JOURNAL

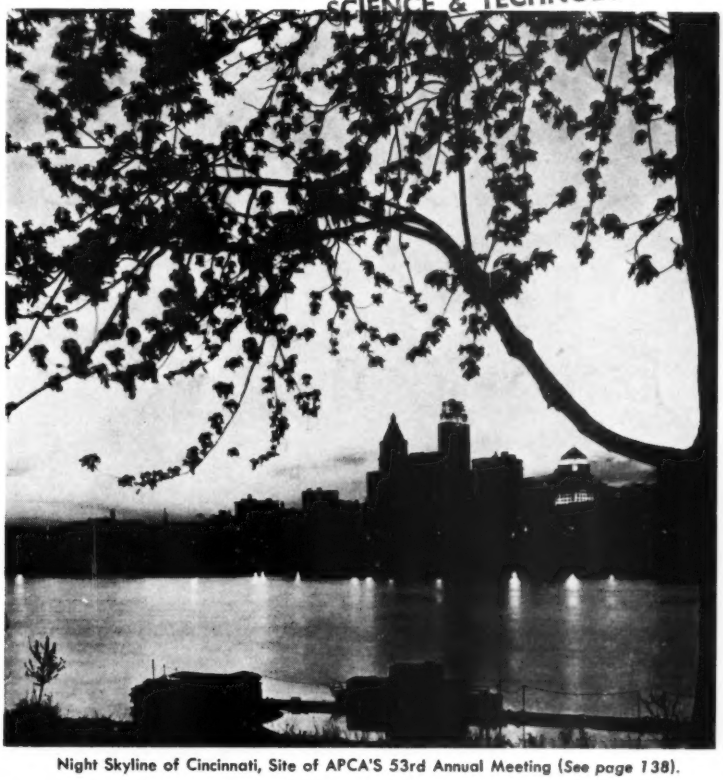
LOS ANGELES PUBLIC LIBRARY
MAY 9 - 1960

AIR POLLUTION CONTROL ASSOCIATION

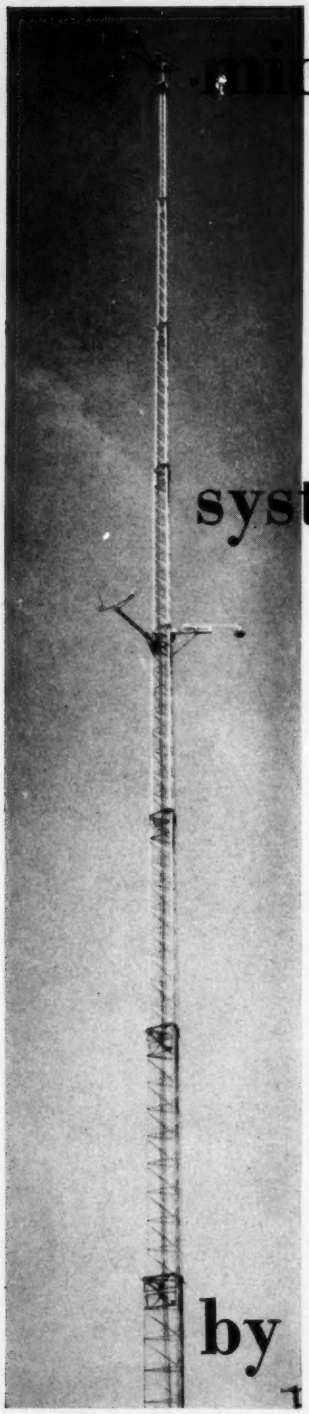
STACKS

Founded 1907

SCIENCE & TECHNOLOGY



Night Skyline of Cincinnati, Site of APCA'S 53rd Annual Meeting (See page 138).



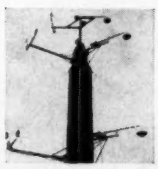
micrometeorological systems engineering

Micrometeorological tower with three stations of wind instruments rises 150 ft above the National Aeronautics and Space Administration's Plumbrook reactor facility at Sandusky, Ohio. This is an example of Beckman & Whitley systems engineering. Standard components are integrated into an installation designed to meet a specialized set of requirements.

Systems engineering personnel from San Carlos provided sensor groups capable of feeding temperature-gradient, ambient-temperature, wind-speed, and wind-direction data to a flexible array of indicating and recording instruments in two special equipment racks.

To provide convenience in access to the sensor equipment, the system was installed and field tested by this group of specialists on a retractable telescoping tower which can be lowered manually or electrically to 32 ft, as shown below.

Your meteorological-system problems can be solved in an efficient, effective way by this group. Their experience is available to you.



by *Beckman & Whitley*

SAN CARLOS 4 • CALIFORNIA

Inset shows the divided collector on each boiler. The "Dutchman" section of breeching downstream from the collectors is provided for future installation of electrical precipitators.

AIRPORT APPROACH SAFETY HELPED BY CLEAN STACKS AT DUKE POWER COMPANY'S ALLEN PLANT

Situated near the Charlotte airport, the Duke Power Company Allen Plant is charged with maintaining clean stacks for greater air safety. Two Aerotec Design 5 RWS mechanical collectors installed on boilers 1 and 2 contribute to the solution of this problem by continuing to exceed guarantees.

Cast white iron tubes, specified for high-abrasion resistance, handle over a million CFM of flue gas from the two boilers. Dust loading at the collector inlet is 1.6 grains per cubic foot.

Joint tests by Duke and Aerotec established dust particle size at 49.7% less than 10 microns. Based on these findings, the Aerotec installation was guaranteed for an overall efficiency of 85.7%. Subsequent operating tests have yielded an efficiency of 87.5%.

Aerotec collectors have been exceeding guarantees for years. If you have any problem in the field of air pollution control, Aerotec's experience with every type of collector assures you of unbiased recommendations on the right type of equipment.

Why not contact us? We are certain to have the answer to your problem.

AEROTEC INDUSTRIES, INC.

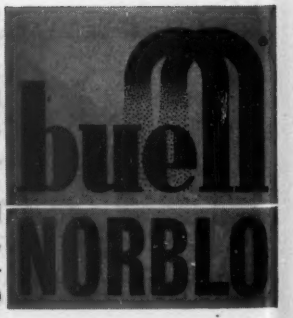
INDUSTRIAL DIVISION, DEPARTMENT U, GREENWICH, CONNECTICUT

CANADIAN AFFILIATE: T. C. CHOWN LIMITED, MONTREAL & TORONTO

FAN-STACKS • BLOWERS • CURTAIN DAMPERS • AIR PREHEATERS • MECHANICAL AND ELECTRICAL DUST COLLECTORS FOR INDUSTRIAL PROCESSES AND FLY ASH • GAS SCRUBBERS FOR CHEMICAL PROCESSES AND NATURAL GAS TRANSMISSION LINES

BUELL-NORBLO
TWO GREAT NAMES
ONE GREAT LINE
OF DUST RECOVERY EQUIPMENT

With the acquisition of The Northern Blower Company, Buell can provide a broad range of products and systems for handling every industrial dust and air pollution problem. Norblo bag type collectors now augment Buell Cyclones and other mechanical collectors, electric precipitators, combination systems and centrifugal and gravitational dust classifying systems. And like Buell, Norblo has been accepted and proved through years of experience in active, on-the-job service. Thus Buell is better able to meet both standard and special requirements in fields that include the electric utilities, steel, oil, cement, chemical, paper, and other process industries. Buell Engineering Company, Inc., 123 William Street, New York 38, New York. Northern Blower Division, 6404 Barberton Avenue, Cleveland, Ohio. (Subsidiary: Ambuco Limited, 2-5 Old Bond Street, London, England)



FOUNDED 1907

JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

A Bi-Monthly Journal
Devoted to
Air Purification

Editor: Arnold Arch
Associate Editor: Pat Truschel
Assistant Editor: Norma Gorst

© Copyright, 1960
Air Pollution Control Association
Printed in the United States

AIR POLLUTION CONTROL
ASSOCIATION
4400 Fifth Avenue
Pittsburgh 13, Pa.

Publications Committee 1959–60

B. E. Sawyer, Chairman
J. C. McCabe
D. H. Hutchison
W. A. Hamor

Editorial Review Committee 1959–1960

W. C. L. Hemeon, Chairman
C. A. Bishop, M. D. Thomas,
G. P. Larson
M. B. Jacobs, D. H. Hutchison
W. L. Faith, H. M. Pier
A. J. Haagen-Smit

The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

THE JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION is published February, April, June, August, October, December with editorial and executive offices at 4400 Fifth Avenue, Pittsburgh 13, Pa.

Second class mail postage paid at Pittsburgh and at additional mailing office.

Subscription price $10.00 per year.
Foreign subscription $15.00 per year.

CONTENTS

APRIL 1960 VOL. 10, NO. 2

Annual Meeting Program and Information 138–142

Controlling the Flue-Fed Incinerator
Robert J. MacKnight, John E. Williamson, Joseph J. Sableski, Jr., and James O. Dealy 103

Attitudes on the Design of Flue-Fed Incinerators
Morton Sterling 110

Effects of Design and Fuel Moisture on Incinerator Effluents
Robert L. Stenburg, Ronald R. Horsley, Robert A. Herrick, and Andrew H. Rose, Jr. 114

Bench-Scale Investigation on Removing Sulfur Dioxide from Flue Gases
D. Bienstock and F. J. Field 121

History of the Air Pollution Control Association
William G. Christy 126

The Smogless Automobile
Fred L. Hartley, C. C. Moore and J. B. Gregory 143

Industrial Zoning as a Means of Controlling Area Source Air Pollution
William D. Holland, Akira Hasegawa, James R. Taylor, and Erwin K. Kauper 147

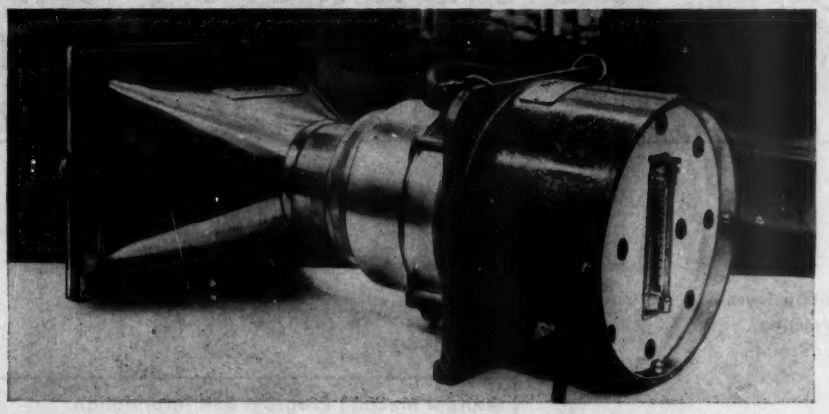
Performance Standards in Zoning
Erwin E. Schulze 156

Design of Afterburners for Varnish Cookers
John L. Mills, William F. Hammond, and Robert C. Adrian 161

Chemical Industry Committee Report
TI-2 Chemical Committee 169

Calendar 172
Editorial 101
Index to Advertisers 120
Letters to the Editor 101
New Members 155
Personalia 175
Section Hi-Lites 172

EASIER, FASTER WAY TO SAMPLE AIR



STAPLEX HI-VOLUME AIR SAMPLER

EASILY PORTABLE.

WEIGHS ONLY 10 LBS.

Accurate to 1/100th micron This is the same air sampler originally developed by the New York Office of the Atomic Energy Commission. Weighs only 10 pounds. Fully portable. Stands up under heaviest usage. Yet, it does in 10 minutes what formerly took 36 hours.

The Staplex samples huge volumes of air by passing it through filter paper 4" in diameter. Special adapters are available for 6x9", 8x10" and 12x12" filters. A turbine-type blower, designed for continuous operation, draws in air at speeds up to 70 C.F.M. Particles as small as 1/100th micron can be accurately sampled, making the Staplex ideal for measuring all types of airborne particulate matter, indoors or out.

Staplex Air Samplers are being used every day to solve the diverse needs of such companies as: Alcoa, Convair, Dow Chemical, Eastman Kodak, Esso Research, The Mayo Clinic, Republic Steel, the Shippingport Power Station—to name a few. Do you have an air sampling problem? Tell us about it.

Available in 110V or 220V AC or DC models; 24V DC. $136.50, f.o.b. Brooklyn, N.Y.

INDUSTRY – beryllium, chemicals, industrial dusts; plant inspections; factory safety programs.

RESEARCH – Missile programs; universities; nuclear equipment.

WEATHER SERVICES – wherever atmospheric conditions must be checked.

NUCLEAR – Radioactive particles, fallout, atomic power plants, missile stations.

GOVERNMENT – Air Pollution Control Departments, Health and Civil Defense Agencies.

WRITE TODAY FOR NEW BROCHURE

The Staplex Company, Air Sampler Division
782 Fifth Avenue, Brooklyn 32, N.Y.

Send me complete information on the Staplex Air Sampler

NAME_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

JACKSON & MORELAND, INC.
JACKSON & MORELAND INTERNATIONAL, INC.

Engineers and Consultants

ELECTRICAL–MECHANICAL–STRUCTURAL

DESIGN AND SUPERVISION OF CONSTRUCTION FOR UTILITY, INDUSTRIAL AND ATOMIC PROJECTS

SURVEYS–APPRAISALS–REPORTS

MACHINE DESIGN–TECHNICAL PUBLICATIONS

Boston—Washington—New York

LAUREN B. HITCHCOCK ASSOCIATES

Chemical Engineers

INDUSTRIAL AIR POLLUTION ABATEMENT

L. B. Hitchcock—Edwin Cox

J. H. Schaefer, Technical Advisor

60 East 42nd Street
New York 17, N. Y.
YUkon 6-4628

HEMEON ASSOCIATES

Air Pollution Research Engineers

APPRAISALS

Control Equipment Performance
Flue Gas and Air Cleaning
Stack Emission Inventories
Community Surveys • Tracer Studies

ENGINEERING

Dust, Fume, Odor Control
Incineration • Catalytic Oxidation
Activated Carbon Applications
Scrubbing • Filtration

W. C. L. Hemeon, Director — Geo. F. Haines, Jr., Chief Engineer

121 Meyran Ave., Pittsburgh 13, Pa.

LETTERS to the EDITOR

Credit Due

Editor:

The December issue of *APCA News* arrived this morning, and, as usual, was full of interesting things to read. One item on Page 4, "Drivers Get Scoop in Columbus, Ohio," was particularly appealing to us.

We are very happy that you have found this pamphlet "clear, concise, and attractively put together."

This pamphlet, now in use in Columbus, was written by this Department and has been in use since 1957. We are, of course, very happy to see that it is being used by other cities, and we are particularly pleased by the comments in the article since we take this to be a tribute to our originality as well as to the fact that Columbus knows a good thing when it sees it.

KENNETH KOWALD
Secretary
New York City Department of Air Pollution Control

The Last Word

Editor:

Contrary to Dr. Quebedeaux's comments on our paper, "Particulate Pollutants in the Air of the United States," (Nov., 1959 J. AIR POL. CONTROL Assoc.) the data on Houston, Texas, samples do not represent collections from different sampling sites, or from more than one station, or from a sampler atop a 12-story building. The sampler in question was approximately 30 feet above street level, and none of the samples reported for it were predominantly cement dust.

In taking exception to the downtown location of the Houston sampling site, Dr. Quebedeaux ignores the widely announced objectives, plan, and limitations of the National Air Sampling Network, as well as its very sound cooperative features. The fact is that the Houston site was chosen by the local health department as being as representative as any one sampling site in a large city can be of the exposure of the population to air pollution.

In objecting to the release of the names of the sampling sites where the data were obtained, Dr. Quebedeaux fails to recognize that this information was released with the consent of the co-operating agencies. He is, of course, entitled to his own fears for the peace of mind of uninformed persons who attempt to interpret broad data in

(*Continued on next page*)

EDITORIAL

Breaking the Log Jam

It is well to re-examine and re-evaluate the purposes of the Association periodically to determine the best way in which to accomplish its objectives. The subject of this editorial was suggested by Article III, Section F, under the purposes of the By-Laws which we quote in part: "—encourage the development and adoption of engineering standards of performance on the national and international scale that are workable and reasonable—."

The implementation of this purpose was accomplished in the By-Laws by Article XV, entitled "Technical Council." This Article outlines the broad principles for guiding the technical Council in its work of establishing definitions, methods, processes, procedures, and recommended practical limits for the guidance of the membership of the society. Since APCA is the only technical association devoted exclusively to the subject of air pollution control, all other technical societies have looked to APCA to exercise leadership in the field of publishing these standards.

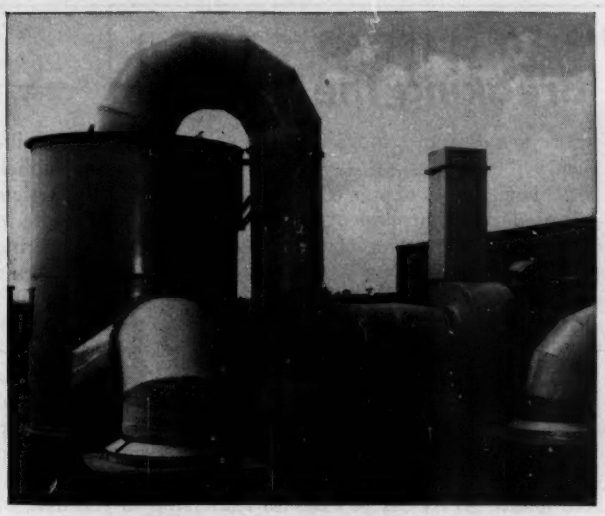
The number of technical co-ordinating committees' reports from the various TI and TA committees that have been published in the JOURNAL as either Tentative Codes, Progress Reports, or Informative Reports, have been far too few since the By-Laws were originally established. What was the reason for this? Under an extremely cumbersome method of approval, if any member of the Technical Council objected or criticized any portion of a committee's report it was returned to the committee, and it was mandatory that the committee completely review and revise this report. Even after the Technical Council finally approved the report (and, this might have taken a period of several years from the time the report was first developed), if any member of the Board of Directors disapproved or criticized the report it was mandatory that this report then go all the way back to the committee once again.

One-Man Veto Power Ousted

We are very happy to announce that the log jam has finally been broken. No longer will one man veto power be available to stymie and frustrate the work of the Technical Co-ordinating Committees and the Technical Council. Your Board of Directors, guided by the Chairman of the Technical Council, Past President Gordon P. Larson, has evolved a new method for handling the transmittal and final publication of the work of these various committees. It has now been left to each committee to decide whether or not remarks or comments of other members of the Technical Council should be incorporated into the reports or rejected.

There is no intention here of putting a rubber stamp on each report. The thinking is this—since these reports must be reviewed annually in the light of new developments and new techniques developed in the field, no report is final but every one is subject to periodic revisions. Once the Technical Council has approved a report, then the Chairman of the Council submits the report to the Board of Directors with a covering letter explaining the status of the particular report. The Board of Directors is then given a suspense date in which to either approve or disapprove the report's publication. Once again a majority of the vote of the Board of Directors is sufficient for publication. There is no longer a one man veto power.

The TA-6 Stoker Committee Report published in the November JOURNAL, the TI-2 Chemical Committee Report appearing in this issue, and the TI-6 Steel Reports which will be published in the June JOURNAL are indications that the work of the committees has finally been recognized. The log jam is broken and we intend to keep the logs hurtling down the river to the sawmill.



Clean Up Your Exhausts With

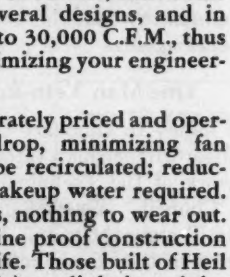
HEIL of Cleveland

FUME SCRUBBERS

Widely used and proven in service, Heil Fume Scrubbers are built in several designs, and in standard sizes from 1,000 to 30,000 C.F.M., thus speeding delivery and minimizing your engineering costs.

Heil Scrubbers are moderately priced and operate with low pressure drop, minimizing fan requirements. Water can be recirculated; reducing the amounts of new makeup water required. There are no moving parts, nothing to wear out. Completely acid and alkaline proof construction assures maximum service life. Those built of Heil Rigidon (reinforced plastic) are light in weight, and usually can be installed on roofs without the added costs of reinforcing beams and trusses.

Let the Heil Corrosion Engineers, with 29 years experience, analyze your requirements, recommend the size and type of standard or special scrubber you need; also the auxiliary collecting hoods, ducts, fans and stacks, so that you have an efficient, dependable, completely corrosion-free system.



Write For Fully Descriptive Bulletins.

CHEMICAL-PROOF LININGS · TANKS HEATERS PLASTICS

HEIL PROCESS EQUIPMENT CORPORATION

12872 Elmwood Ave. • Cleveland 11, Ohio

See Our Exhibit - Booth No. 406

(Continued from page 101)

specific terms. To most observers, however, there is no more reason to be secretive about the National Air Sampling Network report than there is to withhold climatological data on the same city.

Dr. Quebedeaux is in error when he declares that meteorological influences have been disregarded in appraising the data. Indeed, meteorological variations are the chief reasons for differences in the National Air Sampling Network samples from any one station. One of the prime purposes of the statistical methods employed in the data analysis is to identify the range of values by meteorological variables, so that the effect of those variables may be assessed. As for identification of "major components of the particulate," Dr. Quebedeaux should have noted that our paper included a specific reference to a prior publication in which that detailed information is presented.

CHARLES E. ZIMMER
ELBERT C. TABOR
ARTHUR C. STERN
R. H. Taft Sanitary Engineering Center
Cincinnati, Ohio

Next Issue . . .

The June JOURNAL OF APCA will feature many interesting articles on diverse subjects. The steel Committee reports will appear, as well as several quarterly reports on the current activities of other APCA technical committees.

The technical articles will include the following topics:

1. Correlation of dust scrubber efficiency.
2. Industrial ovens for air pollution control.
3. Vegetation symptoms as a measure of air pollution.
4. Meteorological considerations in air quality planning.
5. Total air pollution emissions in Los Angeles County.
6. An objective method for site evaluation.
7. The estimation of air pollution emissions in a regional air pollution control district.

There will be additional articles not mentioned above and up-to-date news items to keep our readers well informed.

We welcome comments from our readers on the content of the JOURNAL. If you have something to add or a correction to make, use the **Letters to the Editor** column, which appears on the preceding page, for communication with the editors and with authors. We want to hear from you!

CONTROLLING *the* FLUE-FED INCINERATOR*

ROBERT J. MACKNIGHT, Principal Engineer, **JOHN E. WILLIAMSON,** Senior Engineer,
JOSEPH J. SABLESKI, JR., Air Pollution Engineer, **JAMES O. DEALY,** Air Pollution Engineer,
Los Angeles County Air Pollution Control District

Single Chamber Flue-Fed Incinerator

Description

An incinerator in which the chimney also serves as a chute for refuse charging, as shown in Fig. 1, is known as a flue-fed incinerator. For some 40 years the single chamber flue fed incinerator has been built as an integral part of apartment buildings. The incinerator usually is located centrally in the building to minimize the distance from the apartments to the charging chutes located on each floor. Occasionally the incinerator may be located on an outside wall with charging chutes outside of the building adjacent to a balcony or fire escape platform. The flue fed incinerator is also used to some extent in schools, hospitals, and office buildings.

The incinerator consists of a box-like combustion chamber separated by dump grates from an ash pit below. Atmospheric gas burners located below the grates are used primarily for dehydration of garbage and other wet material. A cleanout door is provided for removal of ashes from the ash pit. A charging door above the grates is used for igniting the refuse and allows stoking of the burning pile near the end of the burning period. In most instances both doors are provided with spinners for admission of underfire (undergrate) and overfire (overgrate) air. The walls of the incinerator customarily are constructed of two layers of brick. The inner layer consists of $4^1/_2$ in. of firebrick separated by a $^1/_2$ in. air space from a 4 in. common brick exterior. The flue normally is constructed of 9 in. of common brick with a 1 in. flue tile lining. The inside dimensions of the flue usually are 16 in. x 16 in. for apartment buildings 3 to 4 stories in height.

The incinerator is charged through the day by refuse dropped through the charging chutes into the flue. The accumulated refuse normally is burned once each day in the morning. Both spinners are opened, the refuse in the combustion chamber is lighted, and the burners below the grates are ignited. The spinners are left full open and the undergrate burners are kept in operation until the refuse is consumed.

Burning Characteristics

Combustion of the pile of refuse takes place primarily at the surface where air from under the grates and through the overfire air port sweep across the pile. The maximum rate of combustion occurs during the early portion of the burning period when the majority of the dry refuse is consumed. After the initial surface combustion has subsided the burning pile is soaked to uncover additional dry refuse. The heat from the burning of this additional dry refuse and from the undergrate burners dehydrates and ignites some of the remaining moist refuse. Additional stoking supplemented by the auxiliary heat from the undergrate burners assures that the majority of the combustible material is consumed.

Air Pollution Problems

Following the lighting of the refuse the rate of combustion increases rapidly to a maximum and the majority of the dry refuse on the surface of the pile is consumed. The high rate of combustion attained exceeds the necessary rate of air inspiration and results in incomplete combustion and black smoke. Also, the concurrent extreme gas turbulence results in entrainment of large quantities of fly ash (ash and charred paper).

After the initial flash burning of the dry refuse the tall flue and the high firebox temperature produce an excessively high draft. The amount of air admitted through the air ports and minute cracks in the incinerator becomes greater than the demand for combustion air and the temperature in the combustion chamber gradually diminishes as this excess air increases. The combustible gases, oils, tars, and fats, produced by low temperature combustion at the surface of the pile and by destructive distillation within the pile, pass out the stack incompletely burned in the form of white or light gray smoke. This is confirmed by the quantity of volatile material measured by stack analysis.

Large quantities of fly ash also are carried out of the stack from the stoking of the burning refuse pile under excessive draft conditions. The problem is further aggravated by the use of the undergrate burners which entrain fly ash in the hot gases passing through and around the fuel bed. Another problem is the charging of refuse down the flue during the burning period. This smothers and scatters the burning pile and results in smoke production and severe fly ash emission.

From numerous stack analyses conducted on this type of equipment it has been determined that an average of 30 pounds of particulate matter† per ton of refuse burned is discharged. This compares with three pounds per ton for a well-designed multiple chamber incinerator.

Since the inception of the Los Angeles County Air Pollution Control District in 1947 many attempts have been made to control the flue fed incinerator. These attempts have been made by modifying the existing incinerator or by installing control devices in the basement or on the roof.

Basement Control Devices

Three basic problems must be overcome: (1) charging of refuse during the burning period, (2) incomplete combustion and destructive distillation, and (3) excessive draft. Charging of refuse during the burning period is easily and economically eliminated by installing solenoid locks on each of the chute charging doors. These locks are operated by a switch in the basement. The problem of incomplete combustion and destructive distillation requires either the installation of an adequately designed afterburner or revision of the

---

* Presented at the 52nd Annual Meeting of APCA, Statler Hotel, June 23–26, 1959, Los Angeles, Calif.

† Rule 2i, Rules and Regulations, Los Angeles County Air Pollution Control District. "Particulate Matter is any material, except uncombined water, which exists in a finely divided form as a liquid or solid at standard conditions."

incinerator itself to obtain more efficient high temperature combustion. Excessive draft must be reduced either by use of a manually adjustable air port, a barometric damper, or both.

Basement Afterburner

The basement afterburner shown in Fig. 2 is easy and economical to install. A rectangular hole 5 in. high and the width of the flue is cut in the flue above the combustion chamber and a steel frame inserted in the opening to support the stack and the components of the afterburner. Three atmospheric burners rated at 375,000 Btu per hour each are installed along the lower 2 in. of the opening equally spaced across the flue. An air port with a manually-controlled damper is installed in the remaining 3 in. above the burners. Ambient air enters the air port and mixes with the flue gas from the incinerator, thereby reducing the available draft in the basement combustion chamber. The reduction of draft is the result of two factors: the ambient air introduced into the breeching lowers the temperature of the flue gases, and the increased gas volume increases the frictional losses in the flue. When this unit is installed on buildings higher than six stories it is necessary to provide further draft control in the form of a barometric damper.

The principal virtue of this unit is its simplicity. It is easy and relatively inexpensive to install. There are no extra chambers to build. The gas lines to the burners are usually short and consequently inexpensive. The unit is convenient to use—no rehandling of the refuse is necessary.

This afterburner design does not, however, successfully solve all the problems necessary to completely control the flue fed incinerator. It does not provide the flame contact, turbulence, and residence time necessary for this purpose.

With all components of the afterburner most favorably adjusted, the flames from the burners do not completely cover the cross-sectional area of the flue during the first one-half of the burning period, allowing some of the effluent to bypass the afterburner. In addition, the introduction of cold air above the burners tends to quench the secondary burning before combustion is complete. Another deficiency of the design appears when the combustion chamber door is opened for stoking. Additional air then rushes through the open door, entraining fly ash in the flue gases.

There is a potential fire hazard created with this type of installation. Most flues are lined with flue tile, a material not recommended for exposure to afterburner temperatures. The installation of an afterburner in the flue causes an increase in flue gas temperature not anticipated when the incinerator was originally installed. Under the direct flame impingement of the afterburner, flue tile refractories tend to break up and collapse leaving only the exterior red brick, which disintegrates rapidly. The higher stack temperature also increases the temperature of the charging chute doors, creating another hazard.

A typical basement afterburner of this type discharges approximately 15 pounds of particulate matter per ton of refuse burned, as compared with emissions of 30 pounds per ton from an uncontrolled flue fed incinerator. This improvement, however, is not sufficient to enable the unit to meet present air pollution control statutes in Los Angeles County.

Conversion of a Flue Fed Incinerator into a Multiple Chamber Incinerator

The conversion of a basic flue fed single chamber incinerator into a multiple chamber incinerator is shown in Fig. 3. The combustion chamber is charged by refuse dropped through the flue. A damper is installed near the top of the combustion chamber to prevent the gases from passing directly into the flue during the burning period. By closing the damper the products of combustion are diverted through an opening in the side wall into the mixing chamber. Additional air is introduced and secondary combustion is initiated by the flames from the burner. The gases then flow under the curtain wall and into the secondary combustion chamber. Here final combustion takes place and the larger particles of fly ash are deposited. The catalytic units were intended to insure complete combustion of volatiles but stack analyses showed them to be ineffective. From the top of the secondary combustion chamber, the gases pass through a breeching equipped with a barometric damper and into the flue.

When this type of modification is installed, normally little smoke or fly

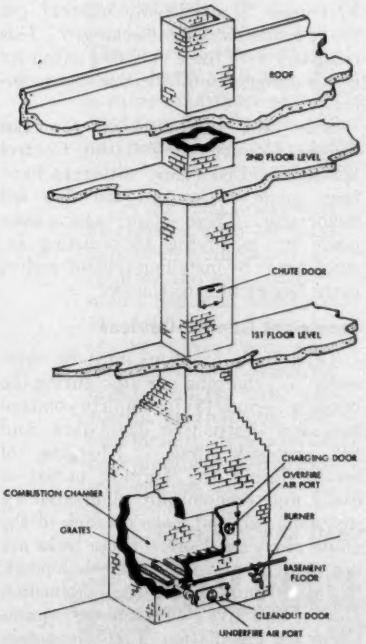


Fig. 1. Uncontrolled flue-fed incinerator.

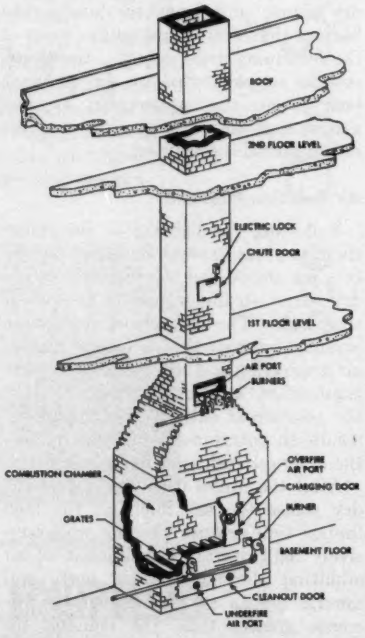


Fig. 2. Flue-fed incinerator controlled by an afterburner at the base of the flue.

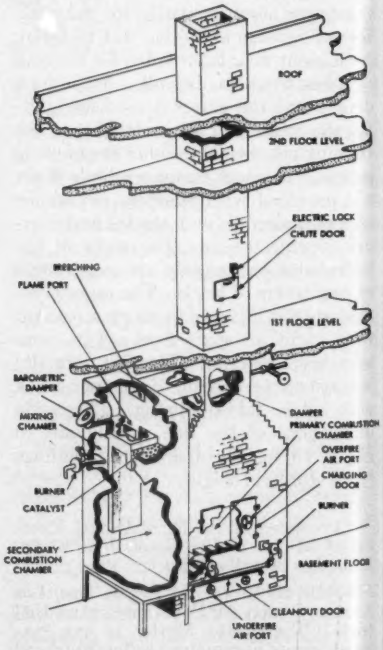


Fig. 3. Conversion of a flue-fed incinerator into a multiple chamber incinerator.

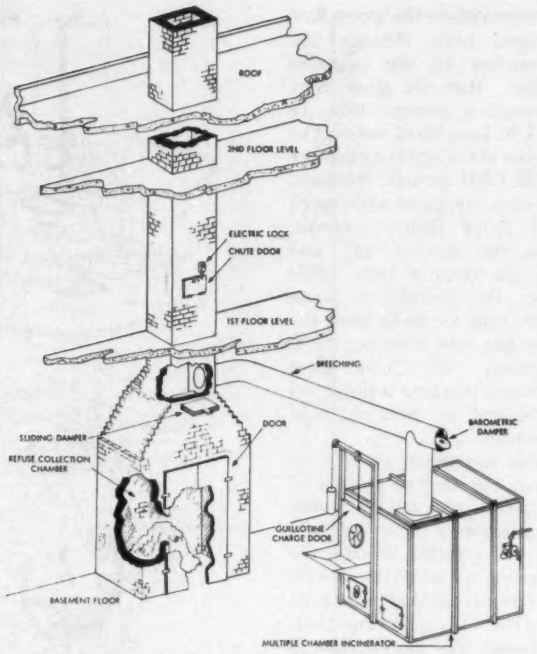


Fig. 4. Flue-fed incinerator modified by the installation of a multiple chamber incinerator.

ash is discharged. When the primary combustion chamber door is opened for stoking the barometric damper remains open as sufficient resistance is provided through the multiple chamber incinerator to prevent the admission of additional air.

After these units were in operation for a year or two large quantities of combustion gases were found to be by-passing the mixing and secondary combustion chambers. This was caused by warpage of the damper, loosening of the damper hinges, and abrasion of the brickwork around the damper which permitted the combustion gases to flow directly up the stack. Observations of some of the units revealed that as much as 75% of the combustion gases were going directly to the atmosphere. Although several different designs of dampers were tried, all were found to have the same weaknesses. Consequently, further attempts to convert flue fed incinerators into multiple chamber incinerators by this method have been abandoned. Tests performed on these units before leakage occurred past the damper revealed a discharge of approximately nine pounds of particulate matter per ton of refuse burned.

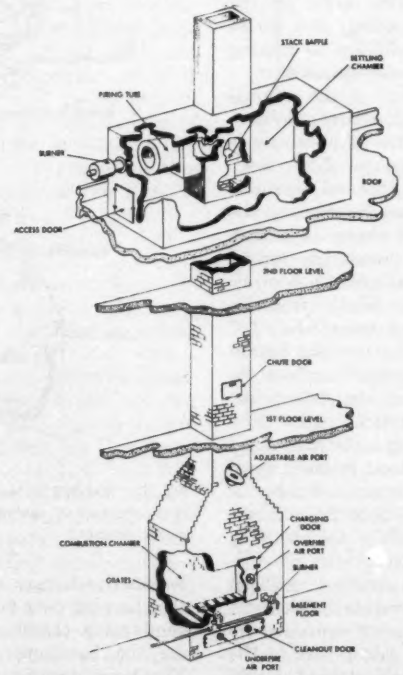


Fig. 5. Flue-fed incinerator controlled by a roof afterburner and a settling chamber.

Multiple Chamber Incinerator Installation in the Basement

Installation of a complete multiple chamber incinerator and conversion of the flue fed incinerator combustion chamber into a refuse collection and storage bin is shown in Fig. 4. Conversion of the combustion chamber is easily accomplished by removing the grates and smoothing the interior walls and floor with plaster. To facilitate the removal of refuse for charging into the new incinerator, a large section of the front wall is removed and replaced by a steel door. A breeching with a barometric damper is installed from the top of the secondary combustion chamber of the multiple chamber incinerator to the existing flue. A steel damper is installed in the flue below the breeching to prevent dilution air from entering the flue through the new collection and storage bin.

The type of barometric damper which is counterbalanced by weights at the top and bottom is used, since this type is most sensitive to small changes in static pressure. It is most important that the barometric damper be sized to admit sufficient air to reduce the draft to an acceptable level. To insure an adequate safety factor, the damper is sized approximately 40% greater than the theoretical size needed. The counterbalance weights are adjusted so that the damper opens at the −0.20 in. w.c. draft that is optimum for satisfactory operation of a multiple chamber incinerator.

During the burning period the solenoid lock on the charging chute doors are actuated and the damper below the breeching is closed. The accumulated refuse is then charged from the storage bin into the new incinerator. Burning is normally carried out once a day as the bin does not provide storage for more than that length of time. When burning is completed, the door to the bin is closed, the flue damper is opened, and the chute doors are unlocked. Provided a properly sized incinerator is installed, the complete burning operation should not exceed one hour.

This modification has all the convenience to tenants of the original incinerator but the operator has the additional chore of removing the refuse from

the bin and charging it into the new incinerator. The tenants are able to charge the refuse in the manner to which they are accustomed, except for the time that the incinerator is in operation. Observations of these units during the burning period have shown that no smoke and only a small quantity of fly ash can be detected at the stack outlet. Tests performed on these incinerators have shown that two to four pounds of combustion contaminants are discharged per ton of refuse burned.

Roof Afterburners

The design of a roof afterburner is also affected by the three problems encountered in the development of basement controls: (1) charging of refuse during the burning period, (2) incomplete combustion and destructive distillation and (3) excessive draft. Two additional problems are created by the installation of an afterburner on the roof: (1) structural support of the afterburner and (2) back pressure. Weight is one of the most important considerations in the design of a roof afterburner. The majority of apartment houses in this area are not structurally capable of supporting a heavy additional load on their roofs. Back (positive) pressure can be created in the flue by resistance to flow of flue gases through a roof afterburner. This can cause smoke to be forced into the building through any cracks or crevices around the charging chute doors where the positive pressure in the flue exists.

A Unique Roof Afterburner

Afterburners designed and built as shown in Fig. 5 were used to control flue fed incinerators in a group of 13-story apartment buildings. The outstanding feature of this design of afterburner is its settling chamber. This chamber is large enough to collect any material carried up the flue from refuse charged during the burning period. Consequently, chute door locks are not needed and the tenants are able to charge refuse at any time.

The afterburner is constructed of concrete with three inches of foam glass block insulation. Its exterior dimensions are 12 ft. long, 9 ft. wide, and 7 ft. high. The chamber is constructed with the flue located at the center of its longest wall—this produces a U-shaped interior. The flue is blocked off by a horizontal partition at a point midway between the top and bottom of the settling chamber. The partition diverts the flue gases through a rectangular hole into one end of the settling chamber. The openings and passageways through the unit are large enough so that the gases pass through the unit without creating back pressure.

Fly ash settles out as the gases flow in an elliptical path through the U-shaped chamber to the opposite side of the flue. Here the gases enter the flue through a ceramic tube 16 in. I.D. and 4 ft. long which extends to within six inches of the settling chamber wall. A 1500 CFH premix luminous flame gas burner, equipped with spark ignition and flame failure controls, fires through the outside wall and directly into the ceramic tube. The effluent from the incinerator must mix intimately with the flame from the gas burner in the tube assuring excellent combustion. The foam glass block insulation in this area is protected from excessive heat by three inches of castable refractory.

Tests of this equipment show it to discharge from one to two pounds of particulate matter per ton of refuse burned. Installation of these large and heavy units was possible because the apartment houses on which they were installed were constructed of reinforced concrete capable of supporting their weight. Although this modification is the most effective control device developed, its usefulness is limited to those buildings whose roofs can support the tremendous weight and where the high initial cost is acceptable.

Laterally Fired Roof Afterburner

The roof loading problem is overcome by mounting the afterburner directly on top of the flue. The flue is dismantled to a height of two feet above the roof and the afterburner is constructed on the flue above this point. This facilitates work on the unit, reduces windloading, and earthquake stresses, in addition to making the completed unit less prominent.

Figure 6 shows one of the original flue mounted roof afterburner designs. The outer shell of the after-burner is constructed of 10-gauge sheet steel, lined with $4\frac{1}{2}$ inches of castable refractory. The inner passage of the unit is built in the shape of a lazy "L." A 1000 CFH premix gas burner, with spark ignition and automatic flame failure controls, fires horizontally into the passage just below the "L." The angular section above the burner provides an impingement surface for the burner flames and also deflects the effluent from its vertical path. The turbulence and mixing of the flames and flue gases in this area produce good combustion. A barometric damper is installed in the flue above the combustion chamber to reduce the draft in the combustion chamber.

The incinerator operates without visible emissions as long as the cleanout and combustion chamber doors remain closed. During the latter part of the burning period, when stoking is required, the inherent weakness of the

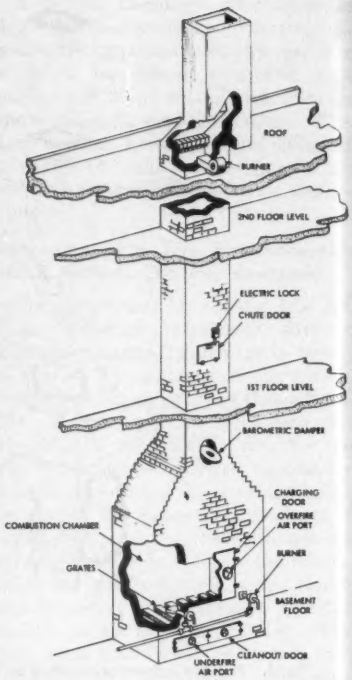


Fig. 6. Flue-fed incinerator controlled by a roof afterburner.

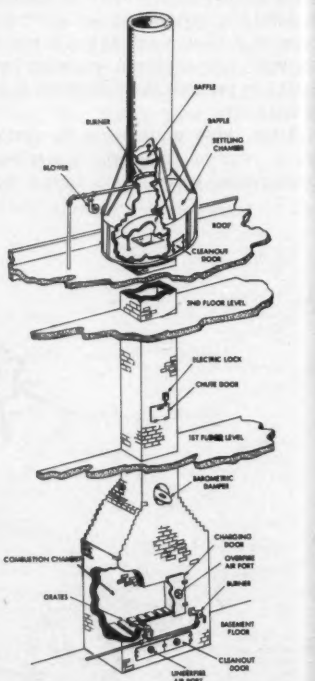


Fig. 7. Flue-fed incinerator controlled by a roof afterburner, settling chamber and barometric damper.

barometric damper is manifested. With the charging door open the draft in the combustion chamber is reduced, causing the barometric damper to close. The large opening of the combustion chamber door permits excessive air flow

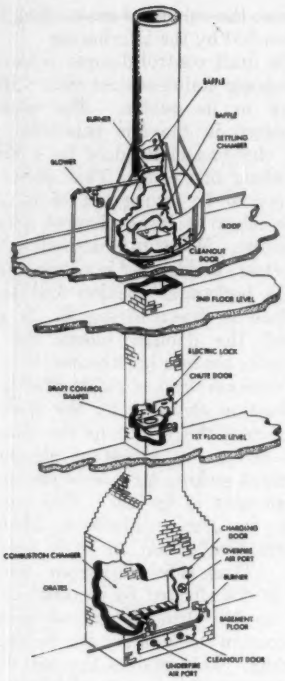


Fig. 8. Flue fed incinerator controlled by a roof afterburner, settling chamber and a draft control damper.

across the remaining refuse on the grates. The turbulence created by the inrush of air together with the stoking operation increases the burning rate and results in the discharge of excessive quantities of fly ash from the flue.

Stack analyses of this equipment have shown it to discharge approximately nine pounds of combustion contaminants per ton of refuse burned, provided the doors of the incinerator are kept closed As this device has no built-in fly ash control and the method of maintaining a stable draft in the combustion chamber is not adequate, this unit is not acceptable in Los Angeles County.

Ring-Fired Roof Afterburner

The afterburner shown in Fig. 7 is composed of three sections. (1) a settling chamber, (2) a combustion chamber and (3) a conical throat with a ring burner connecting the two chambers. The unit is mounted on the flue as described in the previous section. The settling chamber is cylindrical in shape, 3 ft.-8 in. I. D. and 2 ft. high, lined with 1 in. of 2000°F castable refractory. A horizontal circular baffle is located midway between the top and bottom of the settling chamber with a clearance of $2^1/_2$ in. between its circumference and the sides of the chamber. The baffle is constructed either of 12-gauge stainless steel or of $^3/_8$ in. thick cast iron.

The larger area in the settling

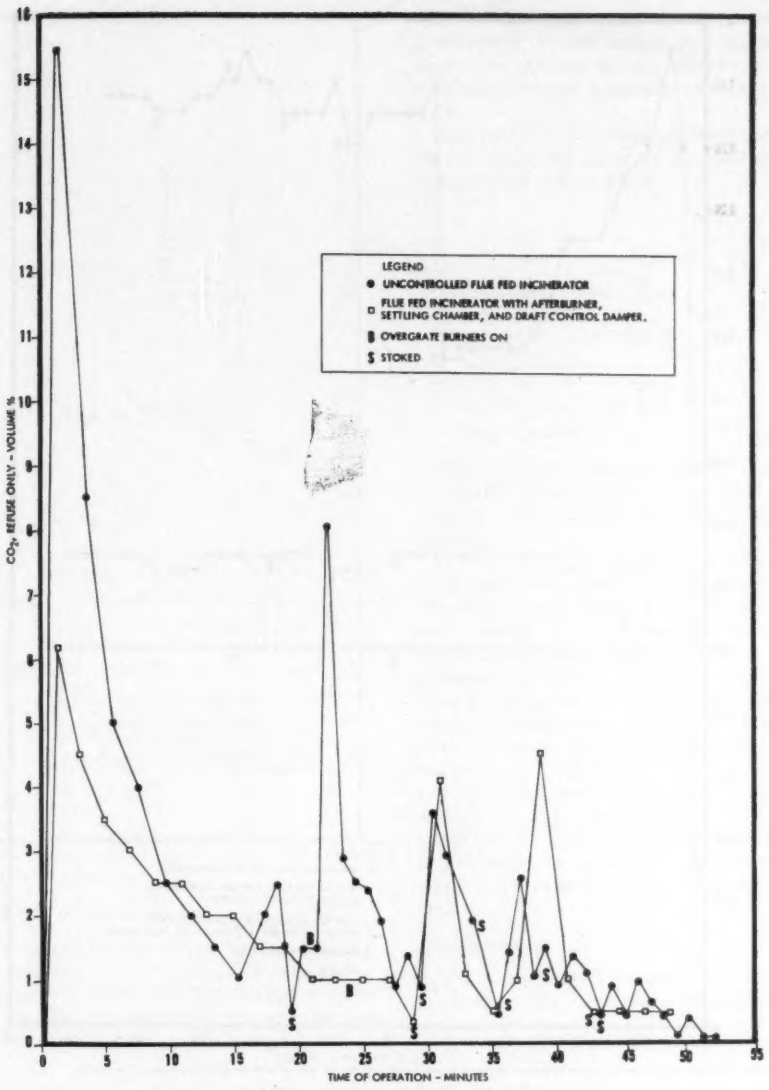


Fig. 9. Carbon dioxide produced from burning of refuse.

chamber reduces the gas velocity to less than one foot per second. The reduction in velocity together with the sharp change in direction in flowing around the baffle deposits nearly all of the fly ash from the gas stream on the floor of the one foot ledge which overhangs the flue. A small door in the side of the chamber is provided for the necessary cleaning.

The gases from the settling chamber pass into a short conical throat 12 in. high having an 18 in. I.D. base and an 11 in. I.D. top. The throat is lined with 2000°F castable refractory 2 in. thick. This section serves to smooth out the flow of gases from the settling chamber and leads them through the center of an 11 in. I.D. ring burner setting directly on top of the throat. The cross section of the burner ring is that of an isosceles triangle. The equal sides of the triangle form the base and outside surface of the burner. The hypotenuse connecting the two legs of the triangle forms the inside surface of the burner. Thirty-six equally spaced $^1/_{16}$ in. diameter holes are drilled through the inside surface of the burner. The burner is designed in this shape to provide a conical flame pattern and yet prevent the flames from being blown out by the rush of flue gases over the surface of the burner.

The 24-in. O.D., 10-foot high combustion chamber begins immediately above the ring burner. The first 16 in. are shaped from 2500°F lightweight insulating refractory to form a venturi. The throat of the venturi is 14 in. in diameter and is located 4 in. above the burner. At the top of the venturi is a 12-in. diameter, 12-gauge stainless steel baffle with 4 in. of annular clearance to the wall of the chamber. Most of the secondary combustion takes place between

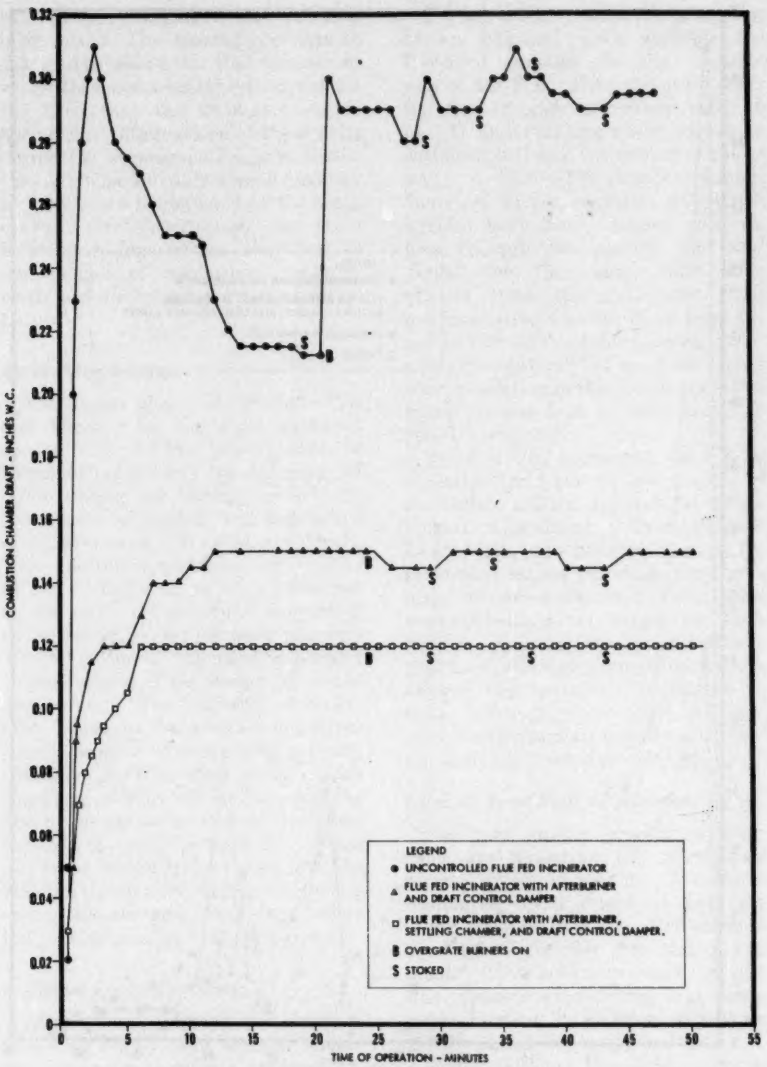

COMBUSTION CHAMBER DRAFT - INCHES W.C.
TIME OF OPERATION - MINUTES
LEGEND
UNCONTROLLED FLUE FED INCINERATOR
FLUE FED INCINERATOR WITH AFTERBURNER AND DRAFT CONTROL DAMPER
FLUE FED INCINERATOR WITH AFTERBURNER, SETTLING CHAMBER, AND DRAFT CONTROL DAMPER.
B OVERGRATE BURNERS ON
S STOKED

Fig. 10. Draft in combustion chamber.

the ring burner and the baffle. Final combustion is completed not more than two feet above the baffle. The additional seven feet of stack is necessary to provide sufficient draft to overcome the resistance of the baffled afterburner section preventing back pressure.

The burner opening, venturi throat, and baffle are sized and placed so that the products of combustion from the refuse must pass through a conical curtain of flame from the burner. All smoke and unburned volatiles passing through the ring burner are brought into intimate contact with the flames. The turbulence provided by the venturi section and the baffle insures good mixing. Additional air may be supplied through a three-inch annular space, formed between the burner and the interior circumference of the combustion chamber.

A small blower mixes 100 cfm of air with 1000 cfh of natural gas prior to its entrance into the burner. This provides a long luminous flame, which is desirable. Because of its remote location, automatic spark ignition, and complete flame failure controls are provided.

A barometer damper in the flue just above the combustion chamber in the basement provides sufficient draft control for buildings of four stories or less. The resultant increase in volume of gases must be considered in sizing the afterburner. By limiting the use of this control equipment to buildings of four stories or less, the afterburner is able to contend with this increase in volume.

Draft Control Damper

A simple but effective answer to the problems of excessive draft and of excessive air intake during basement charging and stoking operations has been found in the draft control damper. This method of draft control, in contrast to the barometric damper, does not increase the volume of gases which must be handled by the afterburner.

The draft control damper consists of a 12-gauge stainless steel plate with an orifice in its center. The plate is supported in the flue below the first floor charging chute door by a hinged rod along one edge. This allows the damper to be swung out of the way while refuse is being charged through the chute. When it is desired to burn the refuse, the damper is swung upward into a horizontal position and locked in place as shown in Fig. 8. So positioned, the damper blocks the flue except for the hole in its center.

A uniform draft is maintained in the combustion chamber by the frictional loss across the orifice in the damper. This limits the inrush of air during basement stoking operations preventing entrainment of fly ash. This uniform draft in the combustion chamber induces combustion air at a constant rate. Thus, the maximum burning rate is not affected by quantity of refuse to be burned, size of primary combustion chamber, or height of building. This enables the size of the afterburner to be standardized for any maximum burning rate desired.

The size of the orifice is dependent on the height and cross-sectional area of the flue, the frictional loss through the afterburner, and the amount of leakage air entering the flue above the damper. The orifice in the draft control damper can be sized by operating the incinerator with the damper in place and adjusting the size of the orifice opening until the desired draft in the primary combustion chamber is attained.

It is necessary to minimize the amount of leakage air entering the flue above the damper in order to obtain the full benefits of this type of draft control. It is recognized that some leakage is inevitable and this factor will limit the height of the building on which this method of draft control can be used.

Effectiveness of Roof Control Equipment

A series of tests were conducted in order to compare the burning rate, draft, velocity, and temperature in an uncontrolled incinerator with those variables in the same incinerator equipped with a ring-fired roof afterburner and draft control damper.

A set of three tests was made on a six story flue fed incinerator under the following conditions.

1 The incinerator was modified as described in the previous section with a draft control damper (orifice area 30 sq. in.) and ring-fired roof afterburner.
2 The baffle in the settling chamber of the afterburner was removed

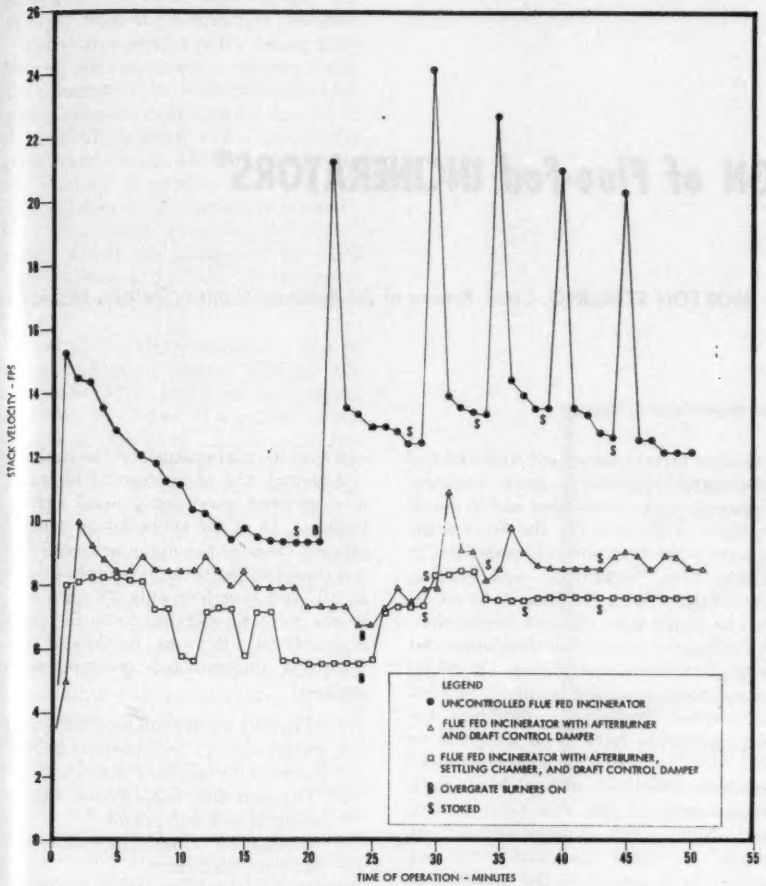

STACK VELOCITY - FPS
TIME OF OPERATION - MINUTES
LEGEND
UNCONTROLLED FLUE FED INCINERATOR
FLUE FED INCINERATOR WITH AFTERBURNER AND DRAFT CONTROL DAMPER
FLUE FED INCINERATOR WITH AFTERBURNER, SETTLING CHAMBER, AND DRAFT CONTROL DAMPER
B OVERGRATE BURNERS ON
S STOKED

Fig. 11. Stack velocity at inlet of afterburner.

to simulate an afterburner with no settling chamber.

3 The unit was operated as an uncontrolled flue fed incinerator with the draft control damper lowered, the baffle in the settling chamber removed, and the roof burner not in operation.

The information obtained from these tests is plotted in Figs. 9 through 13.

Comparison of the draft curves of Fig. 10 shows that both control systems maintain a desirable steady draft of 0.10 in. to 0.15 in. in the combustion chamber and prevent the highly erratic variations in draft shown by the uncontrolled incinerator.

Figures 9 and 11 show that the initial rate, represented by both the percent CO_2 and stack velocity, is reduced by 75% when the draft control damper and afterburner with settling chamber are used. The initial burning rate drops off sharply after the peak is reached. When the refuse pile is stoked or the burners are turned on, the burning rate increases sharply and quickly declines. The burning rate is thus a succession of diminishing peaks.

Figures 12 and 13 show that the steady draft maintained by the draft control damper limits the temperature variation of the flue gases to approximately 150°F, whereas the temperature of the flue gases from the uncontrolled flue fed incinerator varies as much as 350°F. The uniformity of the inlet temperature to the afterburner minimizes the amount of gas required to maintain adequate combustion temperatures.

The results of the stack analyses performed while the previous information was obtained was as follows.

	Discharge in Pounds Per Ton
Uncontrolled Flue Fed Incinerator	30
Afterburner and Draft Control Damper	3.3
Afterburner, Draft Control Damper and Settling Chamber	3.0

From the data above it appears that the draft control damper reduces emissions so that a settling chamber is not needed.

A control system consisting of a roof afterburner and a draft control damper effectively overcomes the problems of roof loading by mounting the afterburner on the flue, eliminates both back pressure in the flue and fly ash emissions by regulating the combustion chamber draft, and does away with smoke emissions by maintaining a high afterburner temperature. All in all, this unit has proved to be most satisfactory in Los Angeles County and appears to be applicable to buildings of even greater height than the six-story buildings on which it has been used up to the present time.

Conclusions

There are two satisfactory methods of controlling the flue fed incinerator.

(*Continued on page 125*)

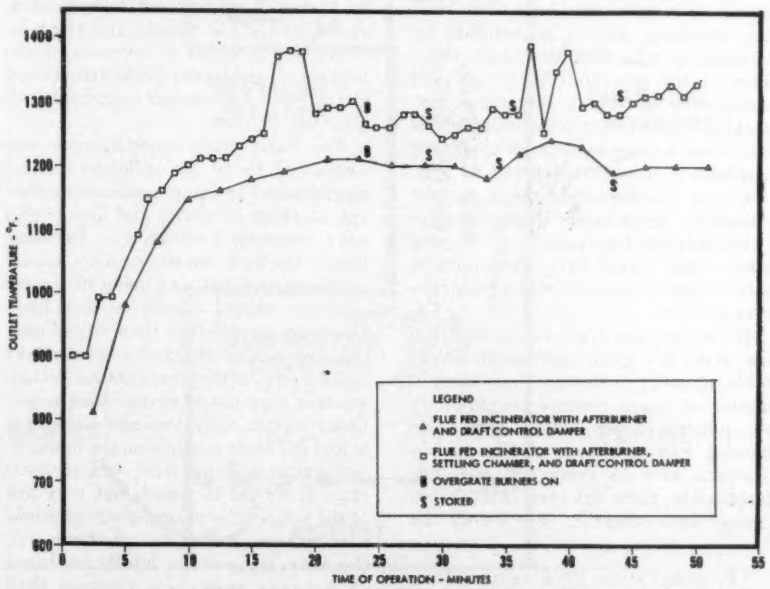

OUTLET TEMPERATURE - °F.
TIME OF OPERATION - MINUTES
LEGEND
FLUE FED INCINERATOR WITH AFTERBURNER AND DRAFT CONTROL DAMPER
FLUE FED INCINERATOR WITH AFTERBURNER, SETTLING CHAMBER, AND DRAFT CONTROL DAMPER
B OVERGRATE BURNERS ON
S STOKED

Fig. 12. Gas temperature at outlet of afterburner.

ATTITUDES *on the* DESIGN *of Flue-Fed* INCINERATORS*

MORTON STERLING, Chief, Bureau of Air Pollution Control, Detroit, Michigan

The apparent diversity of opinion regarding the installation of new flue-fed incinerators which are acceptable from an air pollution standpoint has prompted the writer to undertake a survey of equipment manufacturers' and air pollution control officials' present thinking on the subject. Opinions on the subject from apartment house owners and the general public were not solicited.

It is hoped that this composite report on the various attitudes expressed on the preferred design of new flue-fed units will serve as a guide to interested parties and assist those who presently are considering adoption of an official attitude on the matter. It may be illusory to believe that perhaps this study could eventually promote a common understanding between the air pollution officer and the equipment manufacturer regarding the problem and its solution.

Incineration of refuse "on the site" where it is developed is encouraged by many municipalities as an attractive means to reduce drastically their hauling, dumping, and/or incineration requirements with their attendant costs. The wastes generated in homes and apartments constitute the major percentage of the entire community refuse load, and savings in disposal costs here can lead to substantial overall savings.

Recent developments made by the domestic incinerator manufacturers have evolved a functional device for the home owner and have accomplished this without creating a major air pollution problem.[1]

In the domestic incineration field, the use of flue-fed incinerators as an acceptable disposal technique has been a matter of much controversy from an air pollution viewpoint[2]. The basic flue-fed unit as shown in Fig. 1, was designed over 75 years ago and, unfortunately, there has been little design change until recently. Frequently the nuisance factors associated with flue-fed incinerator operations have counterbalanced their advantages, and in many sections of the country the flue-fed incinerator has been severely restricted in use or even "outlawed," and existing devices have been required to be modified to enable more efficient combustion. An extensive amount of developmental work has been undertaken by many groups to improve the quality of flue-fed incinerator emissions. Notable accomplishments have been achieved in the New York area by joint and independent activities of the New York Department of Air Pollution Control and New York University.[3, 4, 5] It should be noted that this work has mainly been geared to the addition of auxiliary devices on existing incinerators in an attempt to meet modern day air pollution emission standards.

The problem of modifying existing units is separate and distinct from the design requirements for intended new flue-fed incinerator applications. The past poor operating experience manifested by the old designs and the relatively slow progress in successful modification of existing devices has dampened the interest of all parties concerned with their use.

The basic study questionnaire was forwarded to 56 air pollution control agencies and 14 equipment manufacturers, of which 35 (63%) and nine (64%) were returned respectively. In addition to the basic questionnaire, a special additional request was made of the air pollution control officers on such basic questions as whether they would permit installation of flue-fed incinerators in their city; if they were not permitted, whether they would change their minds under certain conditions and what they would be; their attitude on the most objectionable emission from such devices; etc. It should be noted that very few of the people who returned the questionnaire answered all of the questions and, therefore, some of the results are based on a higher percentage response than others and probably would be more indicative of the real attitude on the subject.

Although the percentage of response is considered good for general survey requests, 11 of the air pollution control officials (none of the manufacturers) did not complete the returned questionnaire at all, and therefore only 33 questionnaires were in suitable form for data abstractions. Reasons mentioned for returning uncompleted questionnaires included.

1. "Prohibit use of private or industrial incinerators . . . refuse must be disposed of by sanitary landfill."
2. "Division does not regulate installation of new equipment."
3. "Cannot be of assistance since we have no preference."
4. "Problem of incineration not acute here and we feel that there is insufficient information of a local nature to help your study."

Although some of the data received from the actual 33 respondents was limited, it is believed the results serve a useful purpose. It has been ascertained that 55% of the respondents believe there is a value in the use of flue-fed incinerators. The replies, however, were primarily from the larger cities where multiple story dwellings are common. This report represents the attitudes of those officials and companies who have had much experience on the use of this equipment, and who are in a position to make worthwhile suggestions on preferred future usage.

Results of Answers to Basic Questionnaire

For clarity and ease in referral to the contents of the basic questionnaire the results and some pertinent comments to the various questions are listed below in the order presented.

Preferred Charging Method. There was a marked similarity in the percent response to this question between the air pollution control officials and the manufacturers. Less than 20% of the total number of respondents preferred that charging of the waste be accom-

* Presented at the 52nd Annual Meeting of APCA, Statler Hotel, June 22–26, 1959, Los Angeles, Calif.

plished in the same dust serving the chimney from the combustion chamber.

Thirty-five percent of the respondents favored the combination charging chute and chimney to the combustion chamber with a charging door shut-off damper at the base of the chute and a by-pass for gases from the combustion chamber to the chimney at another level (Fig. 3). This latter system is especially compatible with a multiple chamber incinerator design which has proved to be quite efficient from a combustion standpoint for commercial and municipal applications.

Over 45% of the respondents (50% of the air pollution control officials) felt that there should be a separate charging chute for the refuse to a collection bin located at the same elevation as the incinerator. Charging would then be accomplished by removal of refuse from the bin and manually charging into a separate commercial type incinerator. Since this arrangement is not a true flue-fed incinerator, further comments from respondents favoring this charging method were not tabulated as their design attitudes were applicable to commercial incinerators. The question of the possibility of installing separate refuse chutes to collection bins from a health standpoint was not raised, although it is admitted that many laws, ordinances, and rules prohibit such use. It certainly would appear probable that such bands could be lifted if fire-safe and vermin-free chute-bin combination designs were developed, and there was a strong need shown for their use.

Preferred Basic Incinerator Design. Fourteen percent of the respondents (12% of the air pollution control officials) who expressed continued interest in a flue-fed incinerator design felt that the basic one-chamber unit (Fig. 1) satisfies their present day needs.

Thirty-five percent (37% of the air pollution control officials) prefer a two-chamber design (Fig. 2); whereas, 43% (37% of the air pollution control officials) prefer a multiple-chamber design (Fig. 3).

Grate and/or Hearth Area Sizing. Primary Combustion Chamber Sizing. Burner Sizing. The answers to these questions were so meager (average of only six respondents) that it would be unfair to list the results. Perhaps these questions were unwise to ask in the first instance, for air pollution control officials generally do not dictate equipment design parameters, but leave this responsibility to the equipment manufacturers.

Preferred Type of Auxiliary Burners. All of the respondents answering this question preferred the use of gas as the auxiliary heat source, and 89% of them felt that the burners should be of the "power burner" design, as opposed to the simple atmospheric.

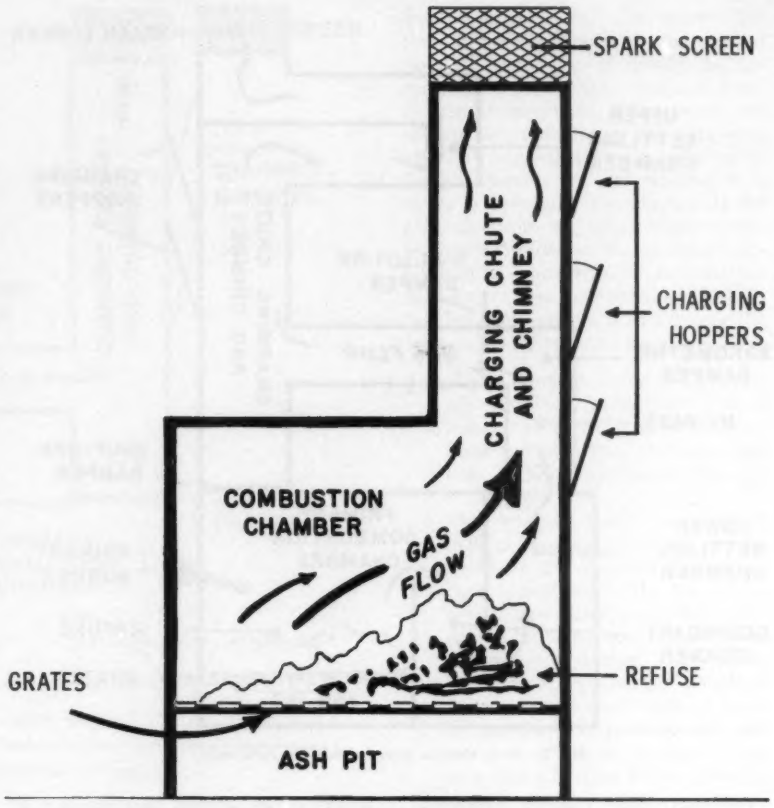


Fig. 1. Basic single chamber flue-fed incinerator.

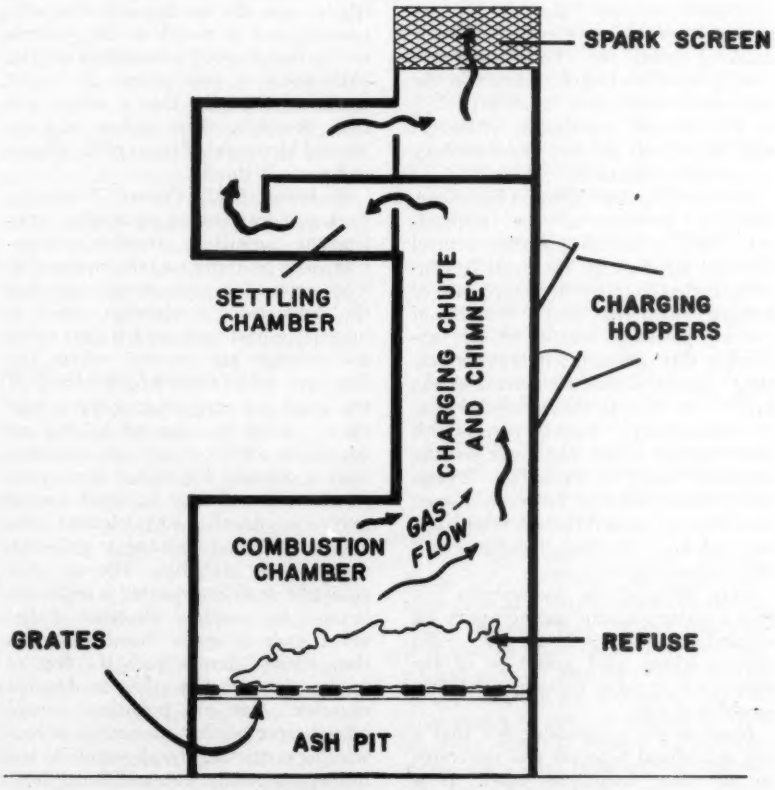


Fig. 2. Basic two chamber flue-fed incinerator.

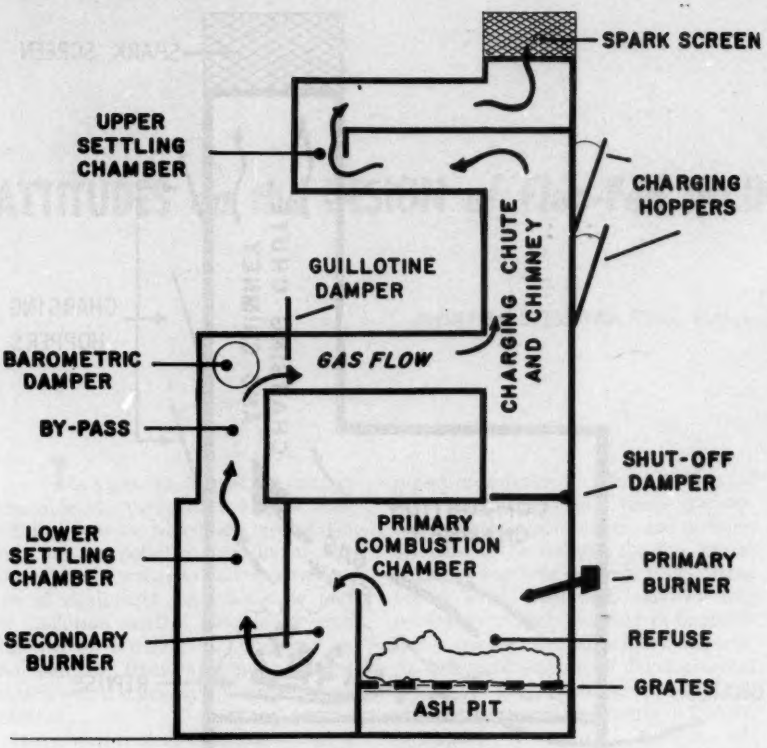


Fig. 3. Basic multiple chamber flue-fed incinerator.

Preferred Odor Control Technique. All of the respondents answering this question felt that odor control should be achieved by the use of auxiliary burners in preference to water collectors, odor masking agents, etc. Forty-three percent favored locating the burner in the secondary combustion chamber; 22% in the primary combustion chamber; and 29% in both primary and secondary combustion chambers.

Preferred Fly-Ash Collection Technique. Sixty-six percent of the respondents (63% of the air pollution control officials) felt that fly ash could be controlled effectively by the simple use of settling chambers. Sixty percent of the air pollution control officials answering this question felt that the settling chamber should be located at the upper level prior to the gas discharge to the atmosphere. Twenty percent felt that both an upper and lower settling chamber would be advisable. Equipment manufacturers, however, leaned more heavily toward the use of both upper and lower settling chambers, with 60% advocating such use.

Only 29% of the respondents felt that a water collector was necessary for efficient collection of the fly ash. Such devices where used would be of the simple spray, water curtain, or venturi scrubber design.

None of the respondents felt that a dry centrifugal collector was preferable to the other techniques cited. It is surprising to note the apparent favoring of the simple settling chamber as a fly ash collection device. Certainly the height of the structure would have some effects upon the needed collection efficiencies, and it would be the writer's feeling that flue-fed incinerators serving buildings over four stories in height would require more than a simple settling chamber. This feeling was expressed by several of the control officials and manufacturers.

Preferred Draft Control Technique. Excessive draft creates combustion problems by permitting excessive combustion air to be drawn into the incinerator. This excess air prematurely quenches the products of combustion, which is inherently inefficient, and it also raises the average gas velocity within the structure, which tends to pick up ash off the grate and carry it into the atmosphere. Forty-two percent of the respondents (50% of the air pollution control officials) felt that a barometric damper was sufficient for draft control purposes. Another 50% felt that both a barometric and a sliding or guillotine damper was advisable. The use of a guillotine or sliding damper is restricted in use to multiple chamber design units, since in single chamber designs they would interfere with the flow of waste materials to the combustion chamber. One air pollution control official reported that his agency is considering restricting the air supply to the incinerator room as an additional draft control technique.

Preferred Time for Burning Waste. Thirty-six percent of the respondents (50% of the air pollution control officials) felt that the waste could be burned at any time. Sixty-four percent felt that the burning should be done at a specific time during the day and various techniques mentioned for the control of the burning time included.

1 Automatically controlled timer mechanism on the main burner which is intermittently ignited by a constant ignition pilot.
2 Locking of the doors at the upper floor at specific periods by automatic timing and solenoid locking mechanisms; indicator lights to be supplied advising tenants when the charging doors are open or shut.
3 Burning during 7 A.M. and 5 P.M., to be controlled by surveillance and inspection.
4 Enlisting the co-operation of the operators to burn at specific periods during the day.

Additional Comments. Seventy-seven percent (of the respondents (85% of the air pollution control officials) felt that charging of the refuse should not be restricted only through the hopper doors, but that refuse could also be charged through the charging door at the incinerator level. The main objection raised to this practice was that opening of the bottom charging door while burning is in progress is undesirable due to the resultant high over-fire air velocities and the physical disturbance of the waste bed by the addition of the new charge which picks up surface fly ash.

Sixty-nine percent of the respondents (71% of the air pollution control officials felt that the flue-fed incinerator should not be restricted for use only in multiple story residential occupancies, but that they would be acceptable for use in such applications as schools, hospitals, nursing homes, etc. The various reasons cited in objection to this practice were.

1 "Dangerous when used for other than multiple story residential dwellings."
2 "Flue-fed incinerator is not a heavy-duty design and is therefore not suitable for hospital wastes."
3 "Nature of waste in residential occupancies is more certain."

Fifty-four percent of the respondents felt that all charging doors should be equipped with interlock mechanisms which would permit charging of wastes only during non-burning periods. One opinion which appears to deserve considerable merit was that door interlocks could conceivably be workable in some instances, but not in others—that it is dependent upon the type of occupancy, such as low, middle, or high rental incomes and their susceptibility to regulation.

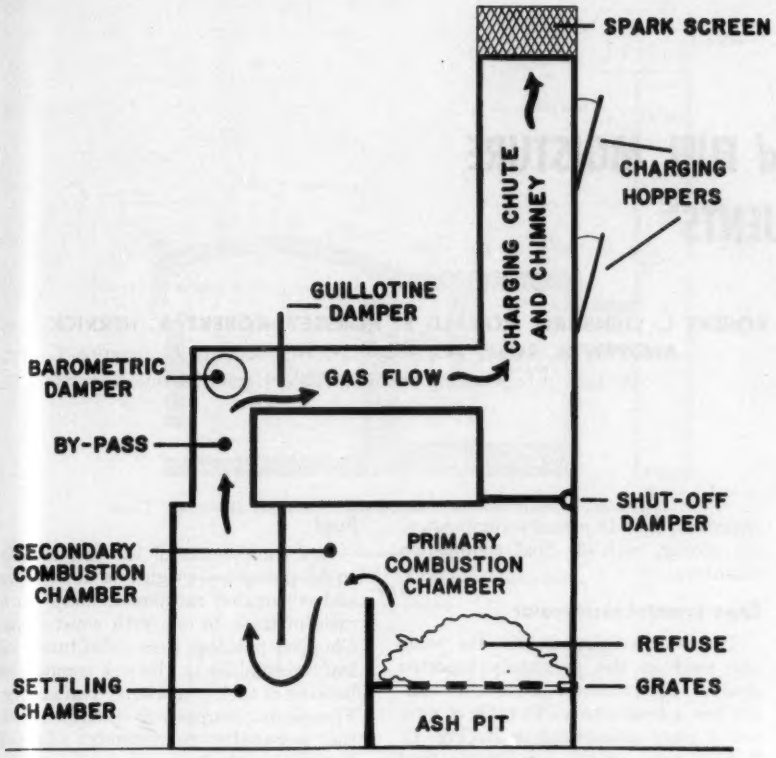


Fig. 4. Preferred composite flue-fed incinerator.

The influence of the height of the building on the various attitudes previously discussed was interesting and varied. Typical expressions were that if the flue-fed incinerator was over three stories in height, they would recommend the installation of a separate commercial incinerator design; that higher structures would affect draft conditions and would increase the tendency for plugging of the waste in the chute; and that increased height means increased draft and a greater need for automatic dampers and more efficient settling chamber designs.

Special Questionnaire to Air Pollution Control Officials

A special questionnaire was forwarded to air pollution control officials only, which asked some pertinent questions on their present feelings regarding the installation of flue-fed incinerators in their jurisdiction. Sixty-nine percent of the officials reported that they would permit installation of new flue-fed incinerators in their areas, while 31% would not. Of those who would grant such permission, almost 30% expressed misgivings about granting it, apparently having insufficient grounds for banning their use.

As previously mentioned, the flue-fed incinerator is generally used in high population centers. Most of the detailed answers were procured from the midwest and northeast regions. Air pollution control officials answering these questions represent a combined jurisdictional area of 25,000 square miles and a total population of 25,000,000 people. It was estimated that the total number of flue-fed incinerators presently installed in the area represented by the air pollution control officials was 19,000, and that there are approximately 500 installations being installed each year.

The air pollution control officials cited odor as the most objectionable emission from flue-fed incinerators (40 %), with fly ash following closely behind (37%), and the balance against smoke.

Findings and Conclusions

An attempt has been made to ascertain present attitudes of air pollution control officials and equipment manufacturers on the preferred design of new flue-fed incinerators.

The basic flue-fed incinerator has undergone little change until a few years ago when the effects of air pollution legislation required that existing units be modified to meet community acceptance.

Fifty-six air pollution control agencies and 14 incinerator manufacturers were contacted, and answers to the questionnaire suitable for data abstraction were obtained from 33 of them. Fifty-five percent of the respondents felt that there is a value in the use of flue-fed incinerators. The balance felt that if incineration were the desired disposal technique, it should be accomplished in suitably designed commercial incinerators. The survey did not enable prediction of the long-term attitudes regarding the installation of flue-fed incinerators and whether it is losing or gaining in popularity. If the consensus from the respondents relative to their attitudes on the preferred features to be incorporated in new flue-fed incinerators were to be used as a basis for the design of the unit, it would have the following distinctive features (Fig. 4).

1. The incinerator would be of multiple chamber construction with a primary combustion chamber, secondary combustion chamber, and both a lower and upper fly ash settling chamber.
2. The wastes would be charged through hopper doors at various levels in the building through a chute connected to the top of the primary combustion chamber. The base of the chute would be provided with a gate or damper which would close when the burning operation proceeded and would thereby force all the gases to pass through the other chambers for treatment and then into a by-pass to the charging chute.
3. The hopper doors would be interlocked with the bottom charging gate or damper so that charging of the refuse could be accomplished only during non-burning periods.
4. The charging and burning would be on a cyclical basis, depending upon application needs, and automatically controlled by timer mechanism and suitable interlocks.
5. Auxiliary gas burners of the "power type" would be installed in the secondary chamber for odor control purposes. There is some leaning toward the installation of both primary and secondary burners. The suggested burner input would vary with incinerator size and assure minimum outlet secondary combustion chamber temperatures of 1400° F.
6. The draft to be controlled by use of both a barometric and guillotine or sliding damper in the by-pass to the charging chute.

It is the writer's personal feeling, based upon his direct knowledge and experience and coupled with the vein in which the replies to the questionnaire were worded, that considerable developmental work is immediately necessary in the design of flue-fed incinerators if they expect to enjoy a substantial role as waste disposal devices in multiple story use. Air pollution experience

(*Continued on page 174*)

EFFECTS *of* DESIGN *and* FUEL MOISTURE *on* INCINERATOR EFFLUENTS*

ROBERT L. STENBURG, RONALD R. HORSLEY, ROBERT A. HERRICK, and **ANDREW H. ROSE, JR.,** Robert A. Taft Sanitary Engineering Center, Division of Engineering Services, Public Health Service, Cincinnati, O.

This report covers the second phase of a study directed towards development of incinerator design standards and criteria for minimizing discharge of atmospheric pollutants from multiple chamber incinerators.

In a previous study[1] involving 32 tests in an incinerator of fixed dimensions, information was obtained on the effects of varying (1) amounts and distribution of combustion air, (2) burning rate as measured by the amount of fuel charged per hour, (3) amount of fuel per charge, and (4) interval between stoking (stirring of the entire fuel bed). From the previous study it was determined that stoking interval, amount of fuel per charge, and secondary air (combustion air introduced just downstream from the primary combustion chamber) had no significant effect on the dependent variables under consideration and could therefore be excluded from future tests. It was also determined that future evaluations of percent excess combustion air, percent underfire air, and fuel feed rate would be more effectively accomplished by increasing the spread between levels tested. By incorporating these changes into the experimental procedure, the number of tests required for each set of conditions and for each incinerator geometry to be tested was appreciably reduced.

Tests reported here were made to determine the effects of fuel moisture content on pollutant emissions from an experimental incinerator of fixed dimensions while varying (1) the amount and distribution of combustion air, and (2) the burning rate as measured by the amount of fuel charged per hour. Future studies will duplicate these identical test conditions with different incinerator geometries in order to measure the effects of design variables represented by the three separate chambers, i.e. (1) primary combustion, (2) mixing, and (3) final combustion chambers.

* Presented at the 52nd Annual Meeting of APCA, Statler Hotel, June 21–26, 1959, Los Angeles, Calif.

Experimental Incinerator

The test incinerator was the same one used in the previously reported study.[1] The primary combustion chamber has a length-to-width ratio of two, and a grate area of 8.5 sq ft (Fig. 1). Volume ratio of the primary to final combustion chamber is 1.06. The present arrangement employs an in-line design with a downpass mixing chamber located immediately behind the ignition chamber. The mixing chamber is followed by the final combustion chamber. Combustion gases from the ignition chamber pass through a high velocity throat over the bridge wall, travel downward through the mixing chamber, and horizontally under a curtain wall to enter the bottom of the final combustion chamber. These gases then travel upward to discharge at the top of this chamber through a short breeching into the stack.

The stack has been lined with a 2 in. thick castable refractory. External modifications include addition of a double-door airlock to permit complete control of combustion air during fuel charging, and a mechanical fuel loader to reduce manpower requirements during a test.

Combustion Air

There were no changes in the point of introduction or the method of measuring air. Overfire combustion air was introduced into the front of the ignition chamber at the grate level, and swept the surface of the burning fuel bed. Underfire air entered through the ash pit and passed up through the fuel bed. Secondary air was introduced through a duct built into the top of the bridgewall and was discharged through a series of ports opening into the top of the mixing chamber.

Fuel

Dry components of the fuel include equal parts, by weight, of newspaper and corrugated cardboard, mixed in a ratio of three to one with wood chips. Chopped potatoes were substituted for leafy vegetables as the wet component because of their year-round availability. Five-pound charges were prepared with the wet-to-dry components adjusted to provide a fuel with an average moisture content of either 25 or 50%.

Sampling and Instrumentation

Except for the measurement of carbon dioxide, sampling and analytical methods were essentially the same for this study as for the previously reported study. The thermal conductivity type analyzer used for carbon dioxide measurement was replaced with a nondispersive infrared gas analyzer. This instrument has a range of 0 to 18% CO_2 and is operated at a wave length of 4.29 microns. Oxygen content was determined by using an instrument employing principles based on the paramagnetic properties of oxygen. Carbon monoxide was continuously measured with a positive type nondispersive infrared analyzer with a range from 0 to 14%. Hydrocarbons were measured with a positive type infrared gas analyzer, sensitized with hexane, with a range from 0 to 750 ppm.

In determining oxides of nitrogen, expressed as NO_2, the Greiss colorimetric method as modified by Saltzman[2] was used. On tests made with 50% moisture fuel, average NO_2 concentrations were determined by taking up to 10 instantaneous grab samples over two or three burning cycles. On tests conducted using 25% moisture fuel, integrated samples[3] were collected over two or more fuel charging cycles. The two methods gave comparable average NO_2 values when used with identical test conditions.

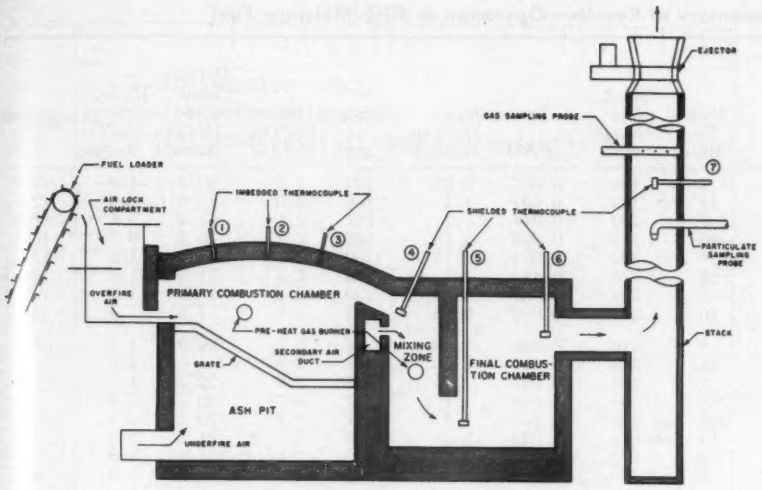


Fig. 1. Schematic elevation of experimental multiple chamber incinerator.

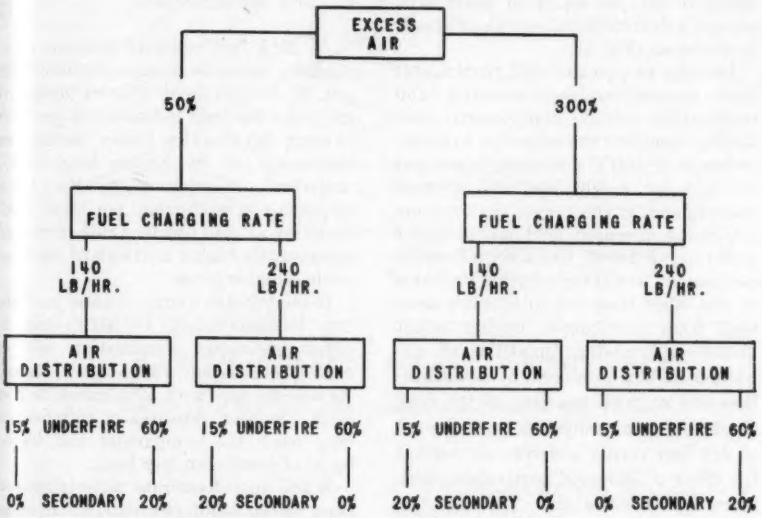


Fig. 2. Experimental design.

Experiment Design

Since excess air, underfire air, and fuel charging rate were the variables previously shown to have the main effects on the production of pollutants, they were further evaluated in this study. Although secondary air was not shown to be a factor of importance in previous testing, it was selected as a fourth variable for these tests since it was felt that it might prove more effective under test conditions producing higher concentrations of hydrocarbons and carbon monoxide.

Although the levels at which the previously reported series of tests were made proved satisfactory for distinguishing major factors affecting pollutant emission, it was also felt that more conclusive data could be obtained by increasing the spread between the levels of most variables.

The experiment design used in this series was a $^1/_2$-fractional factorial with one replication. To evaluate effects of fuel moisture, one set of tests was conducted with 50% moisture fuel and a duplicate set of tests was made using 25% moisture fuel. The variables selected and levels at which they were tested are listed below:

Variables	Levels
Underfire air	15% and 60% of total combustion air
Excess air	50% and 300%
Charging rate	140[a] lb/hr and 240[b] lb/hr
Secondary air	0 and 20% of total combustion air

[a] Equivalent to a grate loading of 16.5 lb/sq ft hr.

[b] Equivalent to a grate loading of 28.2 lb/sq ft hr.

The eight combinations of test conditions resulting from this design are shown in Fig. 2.

Testing Procedure

Conduct of all tests followed the same procedure. The incinerator was preheated initially by gas burners and finally by burning the test fuel, charged at the required rate, and with the proper amount and distribution of combustion air. After surface refractory temperatures in the arch had stabilized and combustion gas temperatures were cycling uniformly over the fuel charging cycle, gas sampling and particulate sampling programs were carried out under uniform operational conditions.

Fuel Charging Technique

While the previously reported series of tests involved an evaluation of the effects of both 10 lb and 15 lb fuel charges, the fuel charge for this series was held at 5 lb. As a result, cycling patterns of gas temperatures, combustion air, and gaseous pollutants were more frequent, had a narrower range, and were more uniform. In the fuel charging procedure a 5-lb charge was introduced through the double-door airlock compartment and was spread out over the front one-third of the grate. Just before introducing a new charge, partially burned material from the previous charge was pushed to the rear of the grate with as little disturbance as possible. This was the only agitation of the fuel bed; there was no stoking and no shaking of grates during a test.

Results

A tabulation of all major findings is contained in Tables IA, IB. The relationship of each contaminant to the experimental variables is discussed in turn. Although the variables are treated separately, statistical evaluation showed effects of interactions between certain of the variables. The variables which caused appreciable effects by themselves, when analyzed separately, were the same variables which caused the interactions to show significance.

Solid Contaminants

1. 50% Moisture Fuel

The following independent variables were found to produce a significant increase in total particulate discharge at their higher levels:

Lb. Total Particulate/Hour:
- *1* Underfire air
- *2* Excess combustion air
- *3* Fuel feed rate

Lb. Total Particulate/Lb. Fuel Burned:
- *1* Underfire air
- *2* Excess Combustion air

Secondary combustion air was not of significance in either increasing or decreasing total particulates at the levels

Table IA—Summary of Results—Operation at 50% Moisture Fuel

Test Conditions													
Excess Combustion Air, %	Fuel Burned, lb/hr	Air Distribution, % Underfire	Secondary	Overfire	Test No. 100-	Stack Discharge, scfm	Particulates gr/scf	Particulates Lb/Ton Burned	Nitrogen Oxides ppm	Nitrogen Oxides Lb/Ton Burned	Carbon Monoxide, Lb/Ton Burned	Hydrocarbons, Lb/Ton Burned	Average % CO_2
50	140	60	20	20	9	184	0.037	0.83	101	1.9	10.3	1.9	12.9
					12	184	0.054	1.2	108	2.0	12.6	1.9	12.8
					7	200	0.049	1.2	121	2.5	17.4	2.5	12.8
		15	0	85	15	186	0.023	0.53	128	2.2	10.3	0.78	13.1
	240	60	0	40	6	322	0.074	1.7	160	3.1	16.2	1.8	13.2
					13	276	0.11	2.1	139	2.3	11.0	1.4	12.5
					2	289	0.031	0.64	132	2.3	16.8	1.2	13.8
		15	20	65	16	259	0.040	0.73	114	1.8	7.5	1.4	12.5
300	140	60	0	40	3	410	0.053	2.6	64	2.7	56.0	1.1	5.4
					11	428	0.047	2.4	68	3.0	—	3.4	6.2
		15	20	65	1	406	0.031	1.5	86	3.6	22.7	1.7	5.7
					5	398	0.023	1.1	77	3.1	29.7	3.9	5.4
	240	60	20	20	10	700	0.18	5.2	67	2.8	30.2	1.2	4.7
					14	618	0.073	3.2	73	2.7	31.3	3.2	5.2
		15	0	85	4	772	0.044	2.4	66	3.0	27.9	1.8	5.8
					8	530	0.032	1.2	83	2.6	13.4	1.3	5.7

tested. Fuel feed rate caused a 133% increase in lb particulate per hour when increased to its upper level. However, total solids discharge per pound of fuel burned was essentially the same whether burning 140 or 240 lb per hour. Total particulate loading per pound of fuel burned was 94% greater at 60% underfire than at 15% underfire. When excess combustion air was increased from 50% to 300%, total particulate discharge per pound of fuel burned increased 125%.

Although the higher level of excess combustion air produced higher total particulate loadings, part of this increase can be considered an effect of underfire air, since the experiment design resulted in an increase of underfire air with increased excess combustion air.

Underfire air appears to be the variable having greatest effect on production of total particulates per hour of fuel burned. Total particulates per pound of wet fuel plotted against SCFM underfire air per sq ft of grate area showed a definite increase with increased underfire air (Fig. 3).

In order to separate solid particulates into noncombustible-nonvolatile and combustible-volatile components, particulate samples were subjected to a temperature of 550°C for three hours and checked for weight loss. If physical entrainment is the major phenomenon producing increased loadings at higher underfire air levels, the noncombustible component would be a better indicator of this effect than the total solids since that total particulate loading might include appreciable quantities of unburned carbon produced by volatilization and thermal cracking of the fuel. A plot of noncombustibles per pound of dry fuel versus underfire air verifies the effect of increased particulates with increased underfire air. This line has essentially the same slope as the line representing total particulates per pound of wet fuel (Fig. 3).

2. 25% Moisture Fuels

At 25% fuel moisture content, comparisons based on pounds of particulate per lb of fuel fired showed underfire air to be the only independent variable causing significantly higher particulate discharges at its higher level (60% underfire). Compared on the basis of pounds of particulate per hour, both underfire air and fuel feed rate produced significantly higher particulate loadings at their higher levels.

No significant change in total particulate loadings could be attributed to either secondary combustion air or excess combustion air at levels tested. As was the case with 50% moisture fuel tests, fuel feed rate was of significance only when the comparison was based on lb of particulate per hour.

When fuel feed rate was increased from 140 to 240 lb per hour, no increase was noted in lb of total particulate per lb of fuel burned. An increase in underfire air from 15% to 60% of total

Table 1B—Summary of Results—Operation at 25% Moisture Fuel

Test Conditions													
Excess Combustion Air, %	Fuel Burned, lb/hr	Air Distribution, % Underfire	Secondary	Overfire	Test No. 25-	Stack Discharge, scfm	Particulates gr/scf	Particulates Lb/Ton Burned	Nitrogen Oxides ppm	Nitrogen Oxides Lb/Ton Burned	Carbon Monoxide, Lb/Ton Burned	Hydrocarbons, Lb/Ton Burned	Average % CO_2
50	140	60	20	20	9	233	0.33	9.4	89	2.1	33.4	2.6	12.8
					12	211	0.33	8.4	98	2.3	22.3	2.0	—
		15	0	85	7	228	0.049	1.4	102	2.5	14.1	1.6	12.3
					15	219	0.16	4.3	90	2.2	20.4	1.7	12.0
	240	60	0	40	6	440	0.13	4.0	106	3.0	20.7	1.4	12.6
					13	348	0.33	8.2	—	—	15.1	2.2	11.4
		15	20	65	2	364	0.044	1.2	106	2.5	—	0.85	13.0
					16	388	0.041	1.1	119	2.6	9.9	0.90	12.0
300	140	60	0	40	3	545	0.045	3.0	47	2.8	—	2.3	5.0
					11	568	0.046	3.2	42	2.6	28.2	0.76	4.6
		15	20	65	1	576	0.027	1.9	46	2.9	—	2.8	5.1
					5	553	0.030	2.0	52	3.2	—	1.8	4.8
	240	60	20	20	10	710	0.089	4.5	50	2.3	18.0	0.55	4.6
		15	0	85	14	920	0.075	4.9	47	2.8	40.0	0.72	4.7
					4	875	0.085	5.3	58	3.2	—	1.8	5.3
					8	915	0.052	3.4	61	3.6	—	1.7	5.0

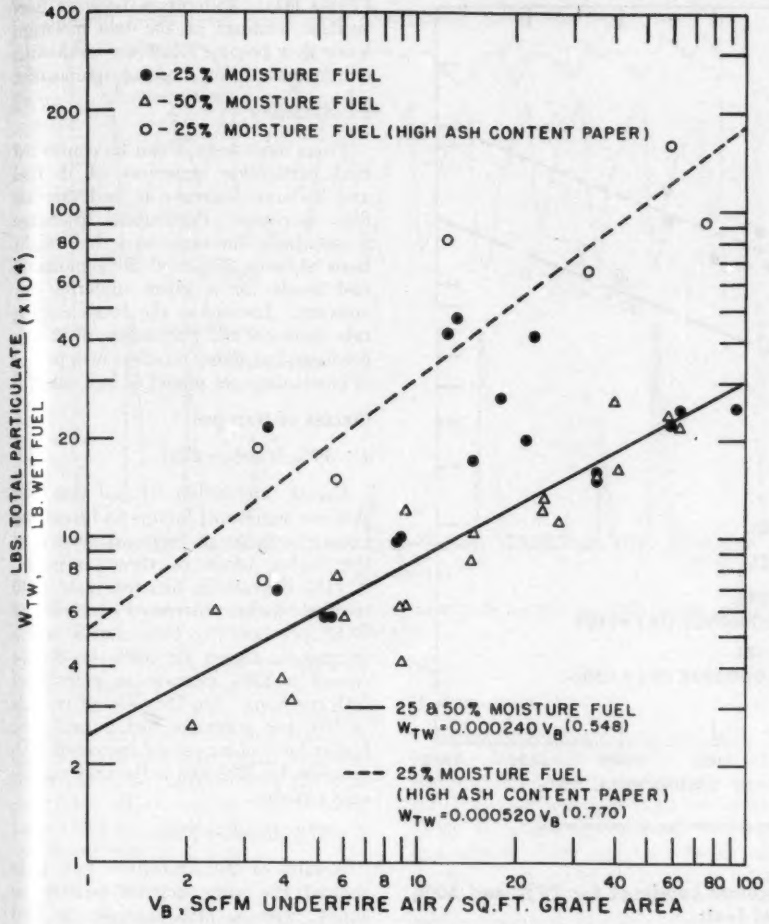

● – 25% MOISTURE FUEL
△ – 50% MOISTURE FUEL
○ – 25% MOISTURE FUEL (HIGH ASH CONTENT PAPER)
W_{TW}, LBS. TOTAL PARTICULATE / LB. WET FUEL (x10⁴)
25 & 50% MOISTURE FUEL
$W_{TW} = 0.000240\ V_B^{(0.548)}$
25% MOISTURE FUEL
(HIGH ASH CONTENT PAPER)
$W_{TW} = 0.000520\ V_B^{(0.770)}$
V_B, SCFM UNDERFIRE AIR / SQ.FT. GRATE AREA

Fig. 3. Relationship of total particulate discharge to underfire air (wet fuel basis).

combustion air resulted in a 137% increase in lb of total particulate per pound of fuel burned. Although underfire air appears to be the primary factor affecting the production of particulates, the plot of total particulates per lb of fuel against underfire air (Fig. 3), has a much greater variation than tests involving 50% moisture fuel, indicating that some factor other than underfire air affects particulates. By separating total particulate loadings into combustible and noncombustible components, and plotting against the noncombustible component, the effect of underfire air becomes more clearly defined.

The combustible component, however, shows no such relationship to underfire air, indicating that this part of the total particulate loading caused the wide variation previously noted. Although the combustible component appears to have some relationship to overfire air, the correlation is not yet well enough defined to justify its expression mathematically. Clarification of this point will be the subject of future investigations.

3. Comparison Between 25% and 50 % Moisture Fuels

In duplicate tests at each of the eight test conditions, 25% moisture fuel gave the highest total particulate loading—8.9 lb of solids per ton of fuel burned—2.1 times the maximum obtained from 50% moisture fuel. This ratio becomes less, however, when dry weight of fuel burned is used as the basis of comparison (Table II), the maximum loadings produced by 25% moisture fuel being only 1.4 times the maximum resulting from 50% moisture fuel. For both levels of fuel moisture content, maximum average particulate loadings occurred when 60% of the total combustion air was supplied under the grate and passed up through the burning fuel bed. Minimum particulate loadings for both levels of fuel moisture occurred when only 15% of the total combustion air was supplied under the grate. Lower loadings were approximately one-sixth (50% moisture) and 1/8 (25% moisture) of maximum loadings.

The effect of fuel composition on the production of particulate discharge was investigated briefly in a few exploratory tests substituting a high ash content paper for the newspaper. With moisture content maintained at 25%, the maximum loading of 31.6 lb of solids per ton of fuel burned was 3.5 times the maximum loading obtained with 25% moisture fuel containing newspaper (Table II).

Total particulate emissions, lb per hour and lb per lb of fuel, increase in proportion to the amount of underfire air with both 25% and 50% moisture fuels. When comparing this relationship on the basis of total particulate loadings per pound of fuel as fired (wet basis), calculated lines for both fuels show no significant difference in either their slopes or intercepts. The relationship between particulates and underfire air for both fuels can therefore be shown as a single line (Fig. 3).

When total particulate loadings from both series of tests are expressed on a dry fuel basis, intercepts and slopes of calculated lines again are not significantly different. As a result, a single line shows the total particulate discharge-underfire air relationship.

A plot of noncombustible loadings per pound of dry fuel vs underfire air was made for both 25% and 50% moisture fuels. Again the resulting slopes and intercepts were sufficiently similar to justify expressing the relationship for both fuels as a single line.

Tests involving fuel containing high ash-content paper were conducted at only the 25% moisture level. However, data plotted in Figs. 3 and 4 give a good indication of variations which can be expected due to fuel composition.

Gas velocities through the final combustion chamber ranged from 163 to 600 fpm for 25% moisture fuel and from 116 to 422 feet per minute for 50% moisture fuel. No correlation between particulate discharge and final combustion chamber velocities was observed for either test series.

The effect of excess combustion air on the production of particulates is not as clearly defined as the effect of underfire air. The higher level of excess air was a significant factor in increasing particulate emissions on only the 50% moisture tests. Failure to show an increasing particulate discharge due to excess air in the 25% moisture series is attributed to greater variation between individual loadings resulting from larger and more erratic occurrences of combustibles in most samples from this series. Had there been less variation in these individual values, excess air would undoubtedly have shown up as a significant factor. The increase in particulate emissions at the high level of excess air can be explained partially by the corresponding increase in underfire air when total airflow is increased.

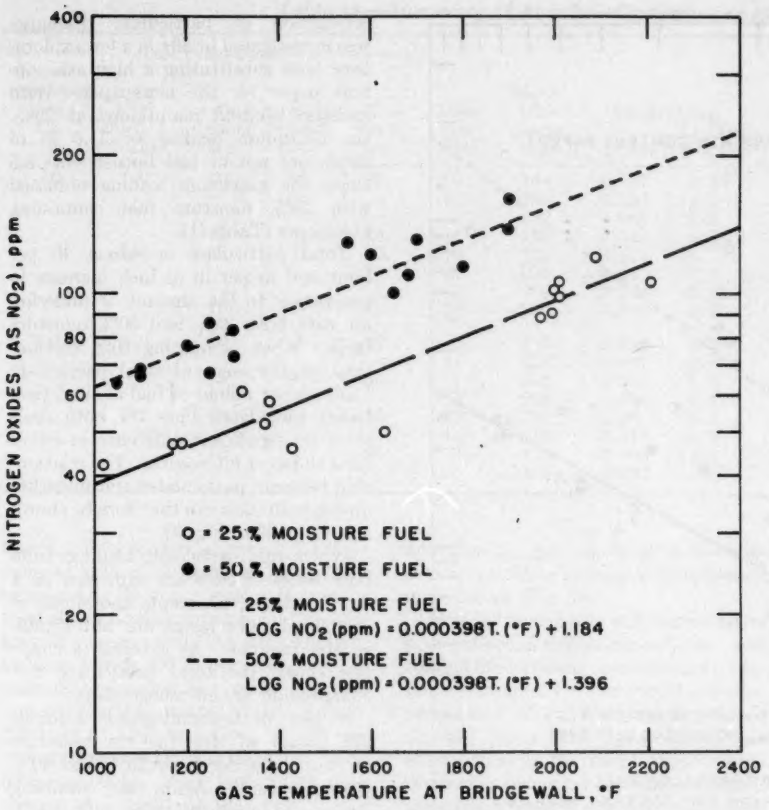

NITROGEN OXIDES (AS NO2), ppm
GAS TEMPERATURE AT BRIDGEWALL, °F
O = 25% MOISTURE FUEL
● = 50% MOISTURE FUEL
25% MOISTURE FUEL
LOG NO2 (ppm) = 0.000398T. (°F) + 1.184
50% MOISTURE FUEL
LOG NO2 (ppm) = 0.000398T. (°F) + 1.396

Fig. 4. Relationship of nitrogen oxides concentration to temperature.

Table II—Maximum and Minimum Particulate Loadings for 25% and 50% Moisture Fuel Tests

Fuel		Underfire Air—	Total Particulate/Ton of Fuel, Lb			
			As Fired		Dry	
Type of Paper	Moisture, %	% of Total	Min.	Max.	Min.	Max.
Newspaper	50	15	0.68	1.82	1.36	3.64
	50	60	1.02	4.23	2.04	8.46
	25	15	1.14	4.37	1.52	5.83
	25	60	3.10	8.90	4.13	11.9
High ash content paper	25	15	1.47	3.72	1.96	4.96
	25	60	13.2	31.6	17.6	42.1

Geometric mean particulate loadings for each level of the four independent variables are given in Table III. When particulate discharges for the two moisture level fuels are compared on a wet fuel basis, loadings at all levels of all variables are significantly higher for 25% moisture fuel than for 50% moisture fuel. Mean loadings for 25% moisture fuel are from 1.5 to 3.5 times the mean loadings obtained with 50% moisture fuel.

A more equitable basis of comparison is possible if particulate loadings are converted from a wet fuel to a dry fuel basis. On this basis, mean particulate loadings for 25% moisture fuel are 1.0 to 2.3 times the mean loadings obtained with 50% moisture fuel, with only 5 of the 8 values having a significant difference.

Since all combustion air was supplied on the basis of established percentages of the theoretical requirement, the total volume of underfire air in tests involving 50% moisture fuel was always less than the total underfire air in the corresponding test with 25% moisture fuel. Therefore, in order to obtain a comparison of particulate loadings for approximately equivalent underfire air velocities at both 25% and 50% moisture levels, an adjustment of the total particulate loadings was made based on the difference between average underfire air velocities at the two moisture levels (Table III). Differences between particulate loadings at the two moisture levels now become relatively small with only one condition showing significance.

4. Summary

From these tests it can be concluded that particulate emissions (lb/lb fuel and lb/hour) increase as underfire air flow increases. Particulate discharge is essentially the same on a dry weight basis at both 25% and 50% moisture fuel levels for a given underfire air velocity. Increasing the fuel charging rate increases the particulate discharge per hour, but shows no effect on a pound of particulate per pound of fuel basis.

Oxides of Nitrogen

1. 50% Moisture Fuel

Excess combustion air and fuel feed rate are significant factors in increasing gross discharge of nitrogen oxides at the higher levels of these variables. A 71% increase in fuel feed rate (140 to 240 lb/hr) increased pounds of NO_2* per hour by 69% and a 500% increase in excess air (50% to 300%) caused a 32% increase in pounds of NO_2 per hour. On the basis of pounds of NO_2 per pound of fuel burned, the higher level of excess air increased NO_2 emission by 32% and is the only significant variable.

2. 25% Moisture Fuel

Results of 25% moisture fuel tests showed the same general pattern as above, with a 71% increase in feed rate increasing pounds of NO_2 per hour by 92% and a 500% increase in excess air showing a 17% increase. When considering pounds of NO_2 per pound of fuel burned, both excess air and feed rate are significant. At their upper levels, fuel feed rate caused an 11% increase and excess air a 16% increase in pounds of NO_2 per pound of fuel burned. The effect of adding secondary air (20% of total combustion air) was a 10% decrease in NO_2 emission on both basis of comparison. Due to the experiment design, such instances of significance must be carefully evaluated before any firm conclusions are drawn.

3. Comparison Between 25% and 50% Moisture Fuels

Fifty percent moisture fuel produced a higher concentration of NO_2 in the flue gas than 25% moisture fuel (Fig. 4). Correlation of NO_2 concentration with temperature is in accord with previously reported data.[1] Considering effluent concentration on the basis of pounds of NO_2 per pound of fuel as fired, it is seen that the NO_2 production on this basis is approximately the same for both moisture fuels (Table IV). On a pounds NO_2 per pound of dry fuel basis, however, the 50% moisture fuel again shows the higher NO_2 production

* The symbol NO_2 is used throughout this discussion to denote oxides of nitrogen, which were determined as equivalent O_2.

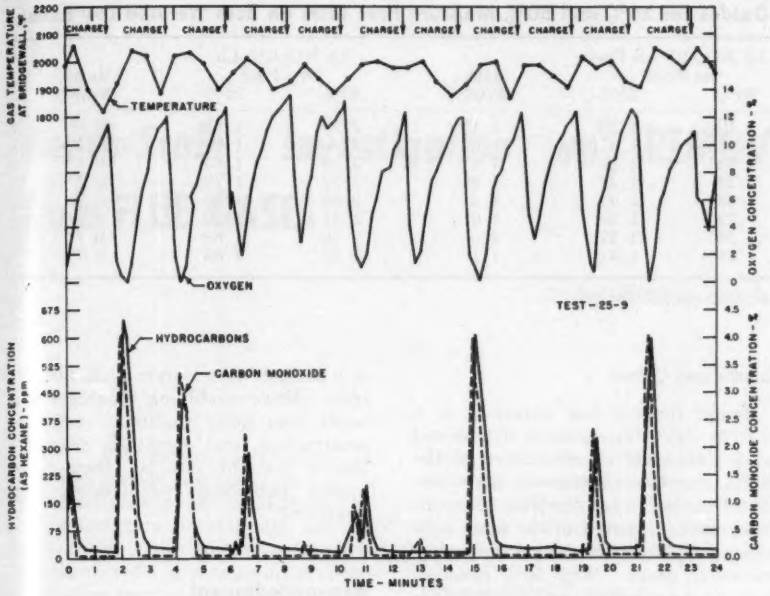


Fig. 5. Production of carbon monoxide and hydrocarbons (25% moisture fuel-50% excess combustion air).

(Table IV). The increase in NO_2 with excess air noted with both fuels is felt to be a possible effect of the increased percentage of oxygen in the incinerator or the resultant increased flame temperatures (not to be confused with gas temperature), either one of which could allow the formation reaction to proceed at a faster rate.

4. NO_2 Summary

Excess combustion air was the variable having the greatest effect on nitrogen oxide discharge per pound of fuel fired. The practice of introducing excess air to reduce furnace temperatures may result in increased NO_2 per pound of fuel burned, but further investigations must be made before conclusions can be drawn. Discharge of NO_2 on a lb per hour basis increases in proportion to increase in fuel feed rate. Increasing fuel moisture content does not appreciably affect the total nitrogen oxide emission per pound of fuel as fired, but does cause an increase on a dry weight basis.

Hydrocarbons

Hydrocarbons were measured with a hexane sensitized infrared analyzer. Although the instrument has zero sensitivity to acetylene and very low sensitivity to ethylene, benzene, acetone, and certain other organic compounds normally encountered in incinerator flue gases, differences in levels of organics produced in these comparative tests can be determined. Calibration gases as low as 10 ppm hexane have been satisfactorily detected by the instrument which has an overall accuracy of ± 2% in the 0- to 750-ppm range.

1. 50% Moisture Fuel

Combustion of fuel with 300% excess air produced average concentrations of hydrocarbons ranging from 14 to 52 ppm with an average of 26 ppm. At the 50% excess air level, average concentrations ranged from 22 to 66 ppm and averaged 45 ppm.

Hydrocarbon production was essentially uniform during 300% excess air tests. Two of the four test conditions conducted with 50% excess combustion air gave uniform production of hydrocarbons during the major part of the burning cycle and, in addition, produced intermittent peaks immediately after introduction of fuel. Maximum peak concentrations ranged up to 385 ppm with occurrence of these relatively high levels of hydrocarbons coinciding with low concentrations of oxygen. Oxygen concentration in the gas stream was between 5 and 6% when peaks began to form and dropped to 2 to 3% when the peak was reached.

2. 25% Moisture Fuel

At the 300% excess air level, hydrocarbon concentrations ranged from 7 to 26 ppm and averaged 13 ppm. At the 50% excess air level the range was from 21 to 58 ppm with an average of 37 ppm.

The pattern of hydrocarbon formation was the same for 25% and 50% moisture fuel. Intermittent peaks occurred in three of the four 50% excess air tests when oxygen concentration had been reduced to between 5 and 6% immediately after fuel charging (Fig. 5). Peak concentrations to 650 ppm occurred when oxygen concentration was momentarily reduced to zero, indicating the importance of maintaining an adequate supply of combustion air.

Carbon Monoxide

1. 50% Moisture Fuel

Carbon monoxide, measured by means of an infrared analyzer, followed exactly the same pattern as the hydrocarbons. Average concentration was 0.12% at the 300% excess combustion air level and 0.11% at the 50% air level. Production occurred uniformly at the high excess air level, but at the low excess air level, intermittent peaks of short duration occurred immediately after introduction of the fuel. A maximum concentration of 2% CO was produced when the oxygen level dropped to 3%.

Table III—Geometric Mean Particulate Discharge for 25% and 50% Moisture Fuel Tests on Both Wet and Dry Bases

		Lb Total Particulate/ 10^3 Lb Fuel as Fired			Lb Total Particulate/ 10^3 Lb Dry Fuel			Ratio	
Moisture Content of Fuel→		(1) 50%	(2) 25%	Ratio, (2)/(1)	(3) 50%	(4) 25%	(5) 50% Adjusted[a]	(4)/(3)	(4)/(5)
Excess Combustion air	50%	0.488	1.73	3.5[b]	0.976	2.31	1.25	2.4[b]	1.8[b]
	300%	1.10	1.66	1.5[b]	2.20	2.21	2.82	1.0	0.8
Underfire air	15%	0.526	1.10	2.1[b]	1.05	1.47	1.35	1.4	1.1
	60%	1.02	2.61	2.6[b]	2.04	3.48	2.62	1.7[b]	1.3
Secondary air	0	0.798	1.84	2.3[b]	1.60	2.45	2.05	1.5[b]	1.2
	20%	0.673	1.56	2.3[b]	1.35	2.08	1.73	1.5[b]	1.2
Fuel feed rate, lb/hr	140	0.620	1.70	2.7[b]	1.24	2.27	1.59	1.8[b]	1.4
	240	0.867	1.69	2.0[b]	1.73	2.25	2.22	1.3	1.0

[a] Lb total particulate/10^3 lb dry fuel for 50% moisture fuel adjusted to equivalent underfire air flow for 25% moisture fuel.
[b] Indicates statistically significant difference at 95% confidence level.

Table IV—Geometric Mean of Nitrogen Oxides for 25% and 50% Moisture Fuel Tests on Both Wet and Dry Bases

Moisture Content of Fuel →		Lb $NO_2/10^3$ Lb Fuel as Fired 50%	25%	Ratio, 25/50%	Lb $NO_2/10^3$ Lb Dry Fuel 50%	25%	Ratio, 25/50%
Excess combustion air	50%	1.10	1.24	1.1[a]	2.20	1.65	0.8[a]
	300%	1.46	1.45	1.0	2.92	1.93	0.7[a]
Underfire air	15%	1.28	1.39	1.1	2.56	1.85	0.7[a]
	60%	1.26	1.29	1.0	2.52	1.72	0.7[a]
Secondary air	0	1.32	1.41	1.1	2.64	1.88	0.7[a]
	20%	1.22	1.27	1.0	2.44	1.69	0.7[a]
Fuel feed rate, lb/hr	140	1.28	1.27	1.0	2.56	1.69	0.7[a]
	240	1.26	1.41	1.1[a]	2.52	1.88	0.7[a]

[a] Indicates statistically significant difference at 95% confidence level.

2. 25% Moisture Fuel

Peak concentrations up to 4% CO were produced with 50% excess combustion air tests, at which time oxygen concentration dropped to zero. Average concentration for 50% excess air level conditions was 0.13%, and for the 300% excess air level was .09%.

3. Comparison of Hydrocarbons and Carbon Monoxide at 25% and 50% Fuel Moisture Levels

Little difference occurred between hydrocarbons and carbon monoxide concentrations from tests made with 25% and 50% moisture fuels. Both series of tests gave intermittent peaks of hydrocarbons and carbon monoxide at the 50% excess combustion air level, and in each case these peak concentrations began to form when oxygen dropped to between 5% and 6%.

Average hydrocarbon concentrations measured were from 70% to 180% higher at the 50% excess air level than at the 300% excess air level.

At levels tested (0 and 20%), secondary air introduced directly downstream from the bridgewall throat was found to be ineffective in reducing concentrations of hydrocarbons and carbon monoxide.

Smoke and Odors

Smoke density was measured as a percent light transmission determined by a photoelectric cell. None of the 300% excess combustion air tests produced smoke, and at the 50% excess air level smoke occurred in the same tests which produced hydrocarbon and carbon monoxide peaks. With 50% moisture fuel, smoke densities were produced up to a No. 2 Ringelman, although these occurrences were intermittent and for only brief periods. With 25% moisture fuel, the intermittent peaks occasionally reached No. 4 Ringelman.

Random observations for combustion gas odors indicated the odor level to be undetectable in the immediate vicinity of the stack.

Conclusions

Values obtained here, taken on an experimental incinerator with closely controlled combustion air, fuel feed rate, and operating conditions are primarily of qualitative value. Because of the basic physical and chemical laws involved, factors demonstrated by this study as affecting the increase or decrease of air pollutants should be the same as those affecting production of pollutants from larger scale incinerators. Since modifying influences can result from many conditions of design, construction, and operation, causative factors brought out by these tests require individual consideration and treatment.

Acknowledgment

Acknowledgment is made to Dr. Eugene K. Harris, Charles E. Zimmer, and Kenneth A. Busch, Analytical Statisticians of the Sanitary Engineering Center, for establishing the experiment design and performing the statistical evaluation of the data.

REFERENCES

1. A. H. Rose, et al., Air Pollution Effects of Incinerator Firing Practices and Combustion Air Distribution. *Air Pol. Control Assoc.*, **8**, 297–309 (Feb., 1959).
2. B. E. Saltzman, Colorimetric Microdetermination of Nitrogen Dioxide in the Atmosphere, *Anal. Chem.*, **26**, 1949–55 (Dec., 1954).
3. R. S. Brief, P. A. Drinker, Collection of Integrated Samples of Gaseous Effluents, *A.M.A. Arch., Ind. Health*, **17**, 654–58 (1958).

Index to Advertisers

Aerotec Industries, Inc. 97
Babcock, Romer, Carberry & Murray, Inc., Philadelphia

Beckman Instruments, Inc. ..... Inside Back Cover
Charles Bowes Advertising, Inc., Los Angeles

Beckman & Whitley, Inc. ..... Inside Front Cover
Gerth, Brown, Clark & Elkus, San Francisco

Buell Engineering Co., Inc. 98
Hicks & Greist, Inc., New York

Day Co. 171
Scrymiger & Osterholt, Minneapolis

Heil Process Equipment Corp. 102
H. T. Bourne Advertising, Inc. Cleveland

Hemeon Associates 100

Lauren B. Hitchcock Associates 100

Jackson and Moreland, Inc. 100

Lockheed Nuclear Products ..... Back Cover

The Staplex Co. 100
Smith, Hegel & Knudsen, Inc. New York

Bench-Scale Investigation on REMOVING SULFUR DIOXIDE from FLUE GASES*

D. BIENSTOCK and **F. J. FIELD**, Supervisory Chemical Engineers,
U. S. Bureau of Mines, Pittsburgh, Pa.

An estimated 21 million tons of sulfur dioxide is released annually to the atmosphere in the United States from the combustion of coal and fuel oil. About 85% of this amount results from combustion of coal, ranging in sulfur concentration from about 0.5 to over 5%, and the remainder from fuel oil ranging in sulfur concentration from near zero to 5%. Combustion of 157 million tons of bituminous coal in 1957 for generation of electric power alone accounted for the discharge of about 8.5 million tons of sulfur dioxide, principally in heavily populated areas. The rapid increase in the demand for electric power will aggravate the problem of pollution from this source.

Because sulfur dioxide irritates the respiratory system of man, can cause extensive damage to plants at very low concentrations, and is corrosive to many types of materials, the desirability of limiting the discharge of sulfur dioxide to the atmosphere has been recognized for a long time. Smelters that discharge gases containing fairly high concentrations of sulfur dioxide were the first to install plants for treating roaster gases before discharge from the stacks. The only commercial installations for treating flue gases of low concentrations of sulfur dioxide (0.05 to 0.3%) from electric power generating plants are in England.[1] Wet-purification processes, which include the Battersea,[2] the cyclic lime,[3] and the ammonia processes,[4] cool the gases from their discharge temperature of about 300°F to about 100°F. The cooled gas, being less buoyant, tends to settle in the vicinity of the stack, so that at times localized pollution is greater, even though most of the sulfur dioxide is removed in the purification process.[5] For this reason, as well as the high cost of the liquid purification processes,[6] the Bureau of Mines, in co-operation with the U. S. Public Health Service, directed research on sulfur dioxide removal to processes employing solids at elevated temperatures, so that the flue gas could be discharged to the atmosphere without further cooling.

Experimental Program

Removal of Sulfur Dioxide

An extensive screening program was undertaken for testing solids as potential absorbents, adsorbents, and oxidation catalysts for removing sulfur dioxide. Figure 1 is a schematic diagram of the bench-scale unit showing the reactor containing a fixed bed of the solid under test and the blending system for preparing a simulated flue gas of the composition.

	Volume-Percent
SO_2	0.3
CO_2	13.0
O_2	6.0
H_2O	6.0
N_2	74.7
	100.0

Experiments were conducted with the feed gas flowing at an hourly space velocity of 1050 [vol of gas (S.T.P.) per hr per vol of absorbent] and with the bed held at 265° or 625°F. These are typical temperatures of flue gases leaving the stack or entering the air preheater, respectively, in a powerplant generating electricity. Sulfur dioxide in the feed and effluent streams was analyzed by absorption in standard iodine and titration with sodium thiosulfate. The solids were 8- to 24-mesh in all of the tests, except for those with molecular sieves of 14- to 30-mesh.

Absorption

Most of the common metallic oxides were prepared and tested as absorbents. The results of these tests are presented in Tables I and II, where the absorbents are listed in decreasing order of absorption efficiency. The absorption values in these and succeeding tables are given as the concentration of sulfur dioxide on the solid when the efficiency of removal decreased to 90%. With most of the

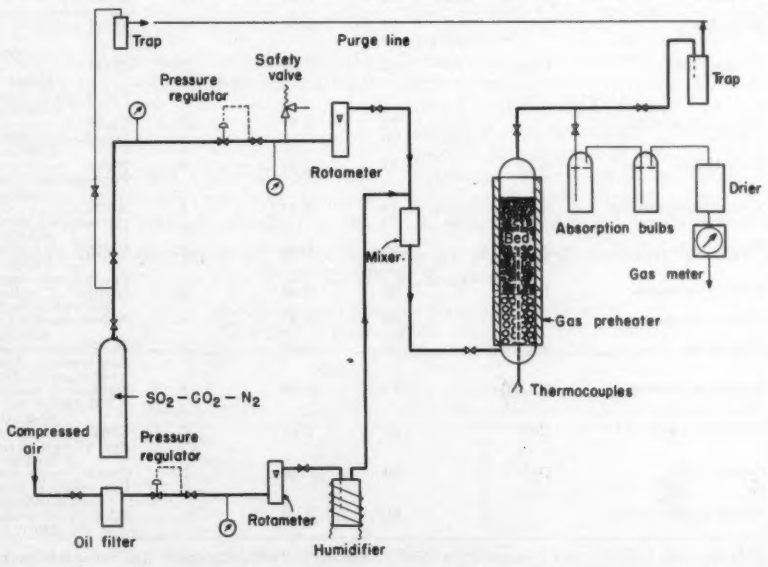


Fig. 1. Bench scale unit.

* Presented at the 52nd Annual Meeting of APCA, Statler Hotel, June 22–26, 1959, Los Angeles, Calif.

active absorbents removal of sulfur dioxide is complete until the absorbent becomes spent and the absorption drops sharply. This is shown with a manganese oxide in Fig. 2.

The most active absorbents tested are the oxides of manganese, cobalt, and copper. The method of preparation is extremely important. Copper oxide prepared by the action of sodium carbonate on copper sulfate (bulk density, 0.89 gm/cm³) absorbed 56 grams of sulfur dioxide for 100 grams of charge, while copper oxide prepared by the thermal dissociation of copper sulfate (bulk density, 1.01 gm/cm³) showed no activity toward sulfur dioxide. Because the thermodynamics for formation of sulfate is generally favorable at these temperatures, the results indicate that surface area and porosity strongly influence the rate and degree of absorption. Considerable penetration of the sulfur dioxide into the solid particles must have occurred with the most active agents at 625°F, because the quantity of sulfur dioxide removed approached the stoichiometric amount for complete conversion of the metal oxides to the sulfate. Over 70% of the stoichiometric amount of sulfur dioxide was absorbed by the oxides of manganese, copper, and cobalt.

Sulfur dioxide is generally removed more effectively at 625°F than at 265°F. Copper oxide and lead oxide were particularly sensitive to temperature, being virtually inactive at the lower temperature. However, the alkalized alumina and the nickel oxide were equally effective at both temperature levels. Preparations containing sodium appear to be more reactive than those containing potassium. This is shown with the carbonates and with the alkalized alumina preparations.

Adsorption by Activated Carbons

Haagen-Smit[7] has reported bench-scale experiments on the use of activated charcoals for removing the oxides of sulfur and nitrogen at 150°F with regeneration of the charcoal at 500–700°F. Several activated carbons some impregnated with metallic oxides, were tested for sulfur dioxide removal, in our studies, at a temperature of 265°F. These results are shown in Table III. In a test at 625°F, however, oxidation of the carbon occurred generating excessively high temperatures. The activated carbons did not adsorb sulfur dioxide at 265°F unless they were impregnated with active metallic oxides such as copper and chromium oxides. With the impregnated carbons, removal of sulfur dioxide occurred through chemical reaction with the metallic oxides. Investigation of activated, impregnated carbons has been temporarily discontinued because the metallic oxides themselves are more effective absorbents and easier to regenerate.

Adsorption by Molecular Sieves

Molecular sieves, which are alkali alumina silicates, with pore diameters of 4 to 13 angstroms, were tested at 265°F. The results of these tests are shown in Table IV.

The molecule of sulfur dioxide has a diameter in the range of 4 to 5 angstroms and therefore is too large to adsorb on the small-pore, 4A molecular sieve and possibly too large for the 5A molecular sieve. Type 13X, with pores the order of 13 angstroms, gave an adsorption of 7 grams of sulfur dioxide for 100 grams of charge, which is comparable to the best results obtained with

Table I—Sulfur Dioxide Absorption Tests at 265°F (130°C)

Hourly Space Velocity of Gas, 1050 Hr^{-1}
Mesh Size of Absorbent, 8–24

Absorbent	Crystalline Phase (X-ray Analysis)	Purity, Weight Percent	Bulk Density, Gm/Cc	SO_2 Absorbed, Gm 100 Gm Absorbent	Preparation
Manganese oxide	MnO 1.88	90	0.14	33	$MnSO_4 \xrightarrow[NH_3]{(NH_4)_2S_2O_8}$ Ppt. washed and dried at 130°C
Cobalt oxide	Co_3O_4	97	0.46	25	$CoSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Manganese oxide	$MnO_{1.88}$		0.50	23	$MnSO_4 \xrightarrow{\text{Electrolysis}}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Manganese oxide	γ-Mn_2O_3	96	0.67	19	$MnSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Aluminum-sodium oxide	Al_2O_3 73 Na_2O 25		0.54	18	$Al_2(SO_4)_3 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated with H_2 at 600–640°C for 20 hr
Hopcalite	CuO 11 MnO_2 79		0.93	13	Dried at 130°C
Cobalt oxide	Co_3O_4	100	0.66	12	$CoSO_4 \xrightarrow[NaOH]{NaOCl}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Chromium-sodium oxides	Cr_2O_3 70 Na_2O 26		0.91	12	$Cr_2(SO_4)_3 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated with H_2 at 600–640°C for 20 hr
Nickel oxide	NiO	91	0.74	9	$NiSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Aluminum-potassium oxides	γ-Al_2O_3 Al_2O_3 73 K_2O 21		0.61	6	$Al_2(SO_4)_3 \xrightarrow{K_2CO_3}$ Ppt. washed, dried at 130°C and heated with H_2 at 600–640°C for 20 hr
Nickel oxide	NiO	90	1.49	6	$NiSO_4 \xrightarrow[NaOH]{NaOCl}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Sodium carbonate	Na_2CO_3	99	0.98	5	Solution of sodium carbonate dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Sodium stannate		95	0.91	4	Sodium stannate, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Iron oxide	α-Fe_2O_3	93	0.98	3	$Fe(NO_3)_3 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated at 300–340°C in a stream of nitrogen for 3 hr
Sodium aluminate	$NaAlO_2$	96	0.90	3	Solution of sodium aluminate, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Cadmium oxide	CdO	97	1.13	1	$CdSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 370–400°C for 20 hr
Copper oxide	CuO	99	0.89	1	$CuSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, compressed at 4000 p.s.i., dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Potassium carbonate		98	0.89	1	Solution of potassium carbonate dried at 130°C and heated in vacuo at 300–340°C for 20 hr

Bismuth oxide (αBi_2O_3), molybdenum oxide (MoO_3), lead oxide (PbO), zinc oxide (ZnO), and calcium hydroxide ($Ca(OH)_2$) absorbed less than 1 gram of sulfur dioxide for 100 grams of charge.

Table II—Sulfur Dioxide Absorption Tests at 625°F (330°C) (90% Removal)

Hourly Space Velocity of Gas, 1050 Hr^{-1}
Mesh Size of Absorbent, 8–24

Absorbent	Crystalline Phase (X-ray Analysis)		Purity, Weight Percent	Bulk Density, Gm/Cc	SO_3 Absorbed Gm 100 Gm Absorbent	Preparation
Manganese oxide	$MnO_{1.88}$		94	0.13	61	$MnSO_4 \xrightarrow[NH_3]{(NH_4)_2S_2O_8}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Manganese oxide	γ-Mn_2O_3		96	0.67	58	$MnSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Hopcalite		MnO_2 CuO	79 11	0.92	57	Dried in vacuo at 300–340°C
Copper oxide	CuO		99	0.89	56	$CuSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, compressed at 4000 p.s.i., dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Manganese oxide	$MnO_{1.88}$			0.50	53	$MnSO_4 \xrightarrow{\text{Electrolysis}}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Cobalt oxide	Co_3O_4		97	0.46	47	$CoSO_4 \xrightarrow{}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Cobalt oxide	Co_3O_4		100	0.66	44	$CoSO_4 \xrightarrow[NaOH]{NaOCl}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Lead oxide	PbO		99	1.23	18	$Pb(NO_3)_2 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Aluminum-sodium oxides	Al_2O_3	Na_2O	73 25	0.54	17	$Al_2(SO_4)_3 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated with H_2 at 600–640°C for 20 hr
Chromium-sodium oxides		Cr_2O_3 Na_2O	70 26	0.91	16	$Cr_2(SO_4)_3 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated with H_2 at 600–640°C for 20 hr
Sodium aluminate	$NaAlO_2$		96	0.90	10	Solution of sodium aluminate, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Nickel oxide	NiO		91	0.74	9	$NiSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Nickel oxide	NiO		90	1.49	7	$NiSO_4 \xrightarrow[NaOH]{NaOCl}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Aluminum-potassium oxides	γ-Al_2O_3	Al_2O_3 K_2O	73 21	0.61	6	$Al_2(SO_4)_3 \xrightarrow{K_2CO_3}$ Ppt. washed, dried at 130°C and heated with H_2 at 600–640°C for 20 hr
Cadmium oxide	CdO		97	1.13	5	$CdSO_4 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated in vacuo at 370–400°C for 20 hr
Sodium stannate			95	0.91	5	Sodium stannate dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Sodium carbonate	Na_2CO_3		99	0.98	4	Solution of sodium carbonate dried at 130°C and heated in vacuo at 300–340°C for 20 hr
Iron oxide	α-Fe_2O_3		93	0.98	3	$Fe(NO_3)_3 \xrightarrow{Na_2CO_3}$ Ppt. washed, dried at 130°C and heated at 300–340°C in a stream of nitrogen for 3 hr
Calcium hydroxide	$Ca(OH)_2$	$Ca(OH)_2$ CaO	81 19	0.36	2	$Ca(NO_3)_2 \xrightarrow{NaOH}$ Ppt. washed, dried at 130°C and heated in vacuo at 300–340°C for 20 hr

Aluminum oxide (γAl_2O_3), bismuth oxide (αBi_2O_3), calcium oxide (CaO), magnesium oxide (MgO) molybdenum oxide (MoO_3), zinc oxide (ZnO), and potassium carbonate (K_2CO_3) absorbed less than 1 gram of sulfur dioxide for 100 grams of charge.

the impregnated, activated carbons.

Oxidation Catalysts

In addition to the use of metallic oxides as absorbents, their use as oxidation catalysts is being studied. A vanadia catalyst was prepared similar in composition to that commercially employed in the contact process for catalytic conversion of sulfur dioxide to trioxide. Chemical analysis of the preparation is shown in Table V. This granular catalyst and several pelleted vanadia preparations obtained commercially were tested at temperatures ranging from 300°C (570°F) to 400°C (750°F). The results of these tests are plotted in Fig. 3.

Significant conversions of sulfur dioxide to the trioxide occurred at temperatures available in powerplant practice. The potash-promoted vanadia catalysts are more active than the unpromoted catalysts. An advantage in using an oxidation catalyst is that it does not undergo chemical change and does not have to be regenerated unless it becomes fouled. The sulfur trioxide formed can be removed by electrostatic precipitation. Vanadia catalysts extruded in the form of tubes are being tested at present. This shape will allow fixed-bed operation with adequate surface area, yet with reduced resistance to gas flow.

Regeneration

Removal of the sulfur dioxide from the simulated flue gas with metallic oxides occurs through oxidation by the oxygen present and reaction of the sulfur trioxide with the metallic oxide to give the corresponding sulfate. Successful regeneration of the spent sulfate involves not only recovery of an active absorbent but recovery of the sulfur in a useful commercial form. Storage, handling, marketability, and selling price of the sulfur product will have considerable influence on the acceptability of a purification process. From the standpoint of demand, sulfuric acid is

Table III—Adsorption of Sulfur Dioxide by Activated Carbons at 265°F (130°C) (90% Removal)

Hourly Space Velocity of Gas, 1050 Hr^{-1}
Mesh Size of Absorbent, 8–24

Type	Impregnated	Bulk Density, Gm/Cc	SO_2 Adsorbed, Gm 100 Gm Adsorbent	Volume SO_2 Adsorbed Volume Adsorbent
ACS[a]	Yes	0.51	8	14
BPL[b]	Yes	0.54	6	10
BPL[b]	No	0.48	0	0
BP[c]	No	0.49	1	2
SGL[b]	No	0.46	0	0

[a] Supplied by Army Chemical Corps
[b] Supplied by Pittsburgh Coke and Chemical. (Made from low-ash coal.)
[c] Supplied by Pittsburgh Coke and Chemical. (Made from high-ash coal.)

the desired product. However, problems of storage, processing, and transporting the acid to a market area could be considerable, especially if there were much disparity between the supply and demand. Elemental sulfur has the advantage in that it can be stored easily on the site and shipped much more cheaply than the acid.

Methods investigated for regenerating the spent solids include thermal, gaseous reduction, and electrolytic techniques.

Thermal Regeneration

Destruction of the metallic sulfate by heat to liberate sulfur dioxide and the metallic oxide requires high temperatures (1300° to more than 1800°F) and generally results in an inactive oxide. Thermal treatment of spent copper oxide and alkalized alumina resulted in liberation of the sulfur dioxide but produced inactive absorbents. Treating these spent absorbents with steam also was ineffective.

Reduction

Reducing gases, such as producer gas, hydrogen, and carbon monoxide, are effective in reducing the temperature of regeneration. The alkalized alumina preparation could be repeatedly regenerated at 1100°F, with the sulfur recovered as hydrogen sulfide plus elemental sulfur. The regenerated absorbent, after passing through a number of absorption-regeneration steps, had lost none of its original activity or suffered any physical attrition.

Electrolysis

With cheap electric power available at a generating station, electrolytic regeneration methods might be attractive. Certain sulfates lend themselves to regeneration by electrolysis. In the electrolysis of manganese sulfate an oxide of a higher valence manganese is formed ($MnO_{1.88}$), together with sulfuric acid at the anode. The oxide is highly reactive, as shown in Tables I and II, and could be reused as absorbent and the sulfuric acid recovered as by-product. The oxide produced in the electrolysis, although not as active on a weight basis as that produced by chemical oxidation with ammonium persulfate, is much more reactive on a volume basis because of its greater bulk density.

Future Studies

In the bench-scale tests a simulated rather than an actual flue gas has been used. To evaluate the effects of fly ash, nitrogen oxides, hydrochloric acid, etc., present in the flue gas, a bench-scale pulverized-coal burner is being built. In addition, a reactor in which falling solids flowing countercurrent to the flue gas, rather than a fixed bed, will be used to approach actual process conditions more closely.

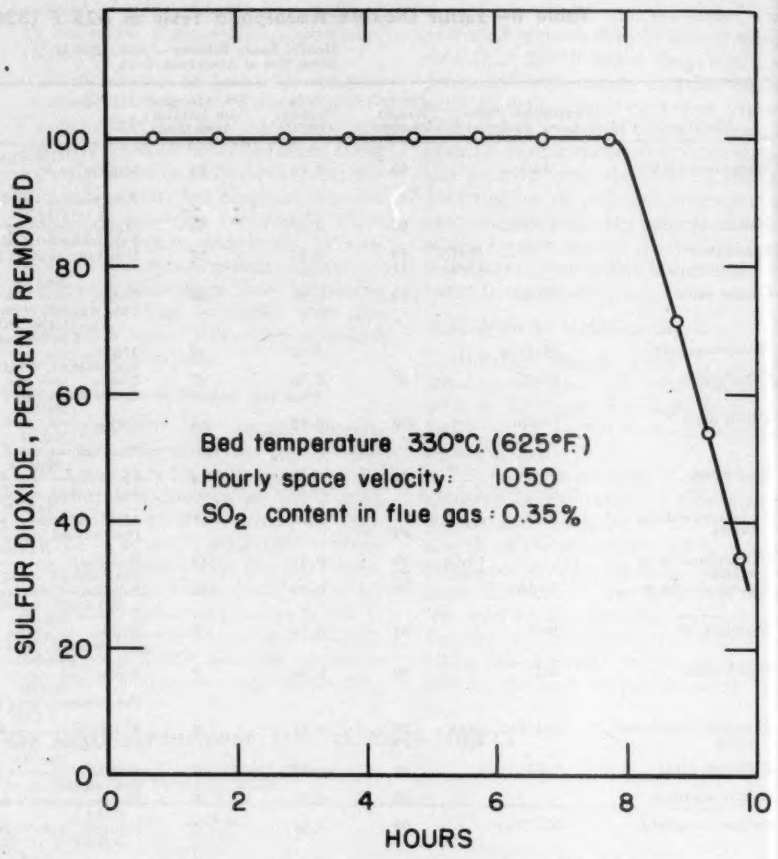


Fig. 2. Removal of sulfur dioxide by manganese oxide ($Mn\ O_{1.88}$).

Table IV—Absorption of Sulfur Dioxide by Molecular Sieves at 265°F (130°C) (90% Removal)

Hourly Space Velocity of Gas, 1050 Hr^{-1}
Mesh Size of Absorbent, 14–30

Type	Bulk Density, Gm/Cc	SO_2 Adsorbed, Gm 100 Gm Adsorbent	Volume SO_2 Adsorbed Volume Adsorbent
4A[a]	0.67	2.3	6
5A[a]	0.67	1.8	4
13X[a]	0.59	7.0	15

[a] Supplied by Linde Co.

Conclusions

As evidenced by the bench-scale tests, removal of sulfur dioxide by using solids from a simulated flue gas at elevated temperatures is possible. Further engineering and cost studies will be undertaken to determine if this technique is feasible on a commercial scale. Although the capital and operating costs for a purification process will of necessity be high, public pressure for cleaner air may require consideration of purification processes by enactment of legislation reducing the allowable concentration of sulfur dioxide in flue gases.

Table V—Chemical Composition of an Alkalized Vanadia Catalyst Dried at 800°F

	Weight Percent
SiO_2	39.6
K_2O	16.5
SO_3	27.3
V_2O_5	7.1
	90.5
H_2O, by difference	9.5
Molar ratio, K_2O/V_2O_5 =	4.5

REFERENCES

1. E. S. Grohse and L. E. Saline, "Atmospheric Pollution: The Role Played by Combustion Processes." *J. Air Poll. Control Assoc.*, **8**, 255–67 (1958).
2. G. W. Hewson et al. "Flue Gas Researches and Battersea Power Station." *J. Soc. Chem. Ind. (Proc.)*, **15**, 67–99 (1933).
3. G. Nonhebel, "A Commercial Plant for the Removal of Smoke and Oxides of Sulfur from Flue Gases." *Trans.*

Faraday Soc., **32**, 1291–96 (1936).
4. S. R. Craxford, A. Poll, and W. J. S. Walker, "Recovery of Sulfur from Flue Gas by the Use of Ammonia." *J. Inst. Fuel*, **25**, 13–14 (1952).
5. R. L. Rees. "The Removal of Oxides of Sulfur from Flue Gases." *J. Inst. Fuel*, **25**, 350–7 (1953).
6. J. H. Field, et al. "Cost Estimates of Liquid Scrubbing Processes for Removal of Sulfur Dioxide from Flue Gases." *J. Air Poll. Control Assoc.*, **7**, 109–15 (1957).
7. A. J. Haagen-Smit, "Studies of Air Pollution Control by Southern California Edison Company." *J. Air Poll. Control Assoc.*, **7**, 251–55 (1958).

Classified

AIR POLLUTION CONTROL ADMINISTRATOR—38 years old, ex naval officer, 12 years experience in Process and Combustion Engineering Application and Operation, M.E. graduate with additional education in Combustion Engineering—Instrumentation—Local and State Government and Public Administration. Six years experience in the organization and administration of local and regional air pollution control programs. Contact Executive Secretary, APCA, 4400 Fifth Avenue, Pittsburgh 13, Pa.

See you in Cincinnati

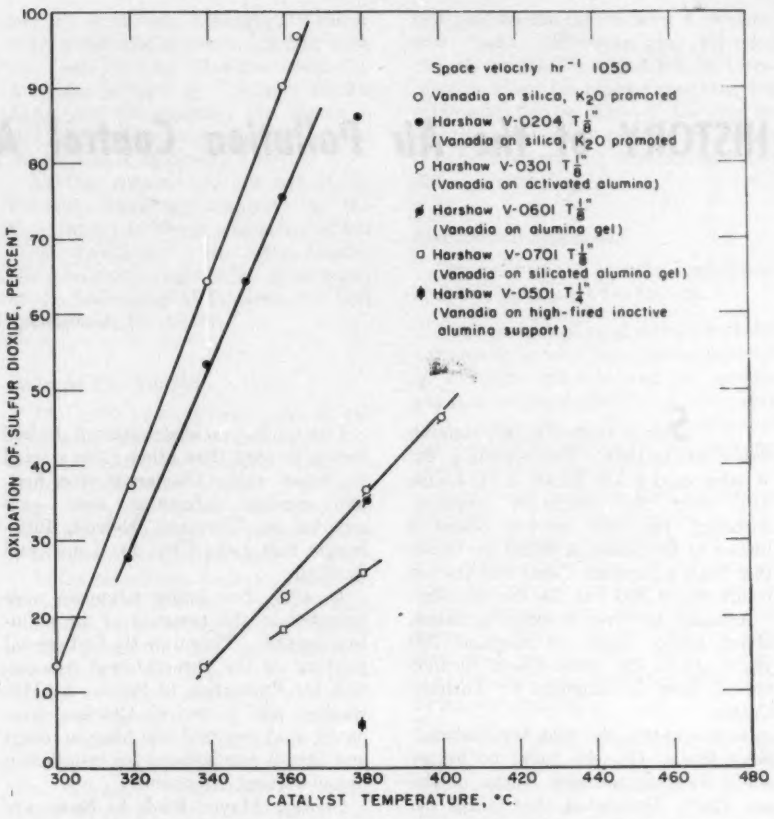


Fig. 3. Oxidation of sulfur dioxide in a simulated flue gas with vanadia catalysts

Controlling the Flue-Fed Incinerator in Los Angeles

(*Continued from page 109*)

(1) by breeching a separate multiple chamber incinerator into the existing flue and conversion of the existing combustion chamber into a storage bin, and (2) by installation of an afterburner on the flue above the roof and a draft control damper below the first floor charging chute.

The separate multiple chamber incinerator installation, costs less initially and will work satisfactorily on buildings of any height. It has the disadvantage of requiring hand transfer of all refuse from the storage bin into the multiple chamber incinerator—a distasteful and time consuming task. A second disadvantage is the amount of valuable basement space occupied by the multiple chamber incinerator which otherwise would be available for tenants' use.

The cost of installing and maintaining a roof afterburner is always greater than installation of a multiple chamber incinerator in the basement. Moreover, the cost differential increases with the height of the building. This increase in cost is primarily due to the additional length and size of gas line required.

Installation of a roof afterburner and draft control damper has the advantage of permitting the refuse to be burned in the original flue fed incinerator. Thus, the refuse does not have to be rehandled. By incorporating a motorized damper and complete electrical interlocking system the unit becomes very simple and convenient to operate.

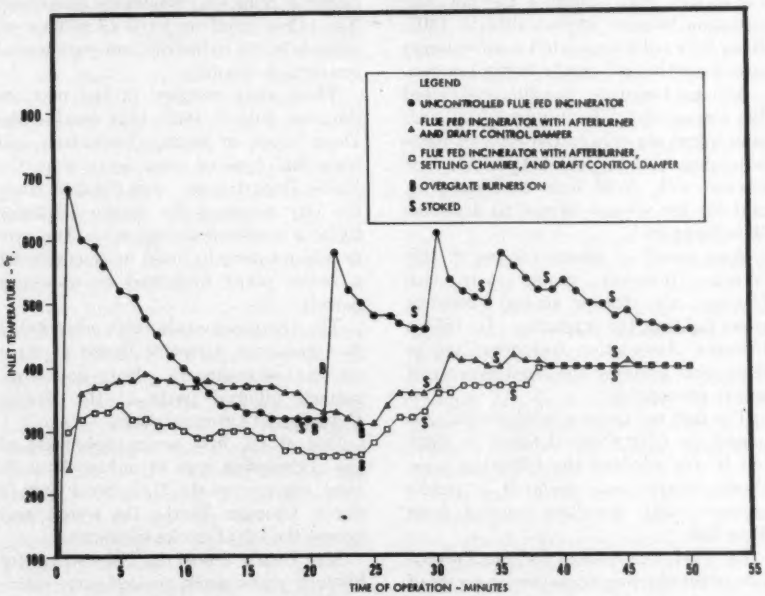


Fig. 13. Gas temperature at inlet of afterburner.

HISTORY *of the Air Pollution Control Association*

WILLIAM G. CHRISTY,
Consulting Engineer, New York, N. Y.

Smoke control in this country dates back to 1864. That's when a Mr. Whalen sued a Mr. Keith in St. Louis, Mo., over the obnoxious nuisance. Although the case started before a justice of the peace, it ended up before that State's Supreme Court and the net result was a $50 fine for the offender.

Actually, however, recorded agitation about smoke began in England 700 years ago, in 1257 when Queen Eleanor moved from Nottingham to Tutbury Castle.

As recounted, she told her husband, King Henry III, she could no longer stand the "unendurable smoke of the sea cole." Translated, that means she couldn't stand the neighbors' burning bituminous coal.

As a result the English Parliament in 1273 passed a law prohibiting the burning of soft coal. Despite the law, the situation became so bad that in 1307, King Edward I appointed a commission to enforce the anti-smoke law in London.

In legal language, the king instructed the commission "To inquire of all such who burnt sea-cole in the city, or parts adjoining, and to punish them for first offense with great fines and ransoms, and for the second offense to demolish their furnaces."

Any record of smoke control in this country, however, should start with Chicago, the pioneer among American cities fighting the nuisance. In 1874 a Citizens' Association was organized to determine some of the legal aspects of smoke prevention.

The first try to get a smoke ordinance passed by City Council failed in 1880, but it was adopted the following year. Dense smoke was declared a public nuisance with penalties ranging from $5 to $50.

By 1891, the Society for the Prevention of Smoke was organized, a group of citizens with the avowed purpose of having Chicago clean as possible for the visitors to the Columbian Exposition in 1893. With private citizens picking up the entire tab, engineers and firemen were instructed in the proper methods of burning bituminous coal.

Chicago had no sooner started the ball rolling in 1881 than other cities started to follow suit. Cincinnati was first, and similar ordinances were soon adopted by Cleveland, Detroit, Pittsburgh, Salt Lake City, St. Louis, and St. Paul.

In 1907, two major advances were recorded in the progress of air pollution control. They were the first annual meeting of the International Association for Prevention of Smoke, at Milwaukee, and a revised Chicago ordinance that required the filing of plans and permit applications for installation of fuel burning equipment.

Chicago Mayor Fred A. Busse appointed the Smoke Abatement Commission, eight private citizens, who helped him decide city policy. Thomas E. Donnelley, president of R. R. Donnelley & Sons Co., was made chairman. The other members were all prominent officials of big industrial and commercial concerns in the city.

Their work resulted in the new ordinance, July 8, 1907, that created the Department of Smoke Inspection and took that type of work away from the Boiler Department. For the first time, the city required the smoke inspector to be a mechanical engineer. And any person wanting to build or re-construct a boiler plant first had to obtain a permit.

The commission also was empowered to appoint an Advisory Board of three mechanical engineers. Both bodies remained integral parts of the Smoke Department for many years.

One of the first accomplishments of the commission was to induce Paul P. Bird, engineer of the U. S. Steel Corp.'s South Chicago Works, to resign and accept the job of smoke inspector.

Mr. Bird's report in 1911, covering his four years' work, reveals some interesting items. He had selected as his deputy smoke inspector, Lloyd R. Stowe. He's the man who later became one of America's leading combustion engineers and the inventor of the Stowe Stoker. Another deputy was Frank A. Chambers, who later headed Chicago's smoke control department and for years was secretary-treasurer and a prime mover in the Air Pollution Control Association.

Association Beginning

By 1906, several cities had smoke inspectors on the job. Detroit's chief inspector, John M. Fairgrieve, promoted the idea of a meeting of other inspectors and city officials in Detroit, and 55 turned out for the three-day affair. The presiding officer was J. M. Hartman a Philadelphia millionaire who was interested in smoke control in connection with civic improvement. Thirteen American and Canadian cities were represented.

It was then it was decided that an association should be formed on an international scale, with the first meeting to be held the following year in Milwaukee.

The active membership was limited to municipal smoke inspectors, and the following officers were elected: Mr. Fairgrieve, president; Charles P. Poethke, vice president, and R. C. Harris, secretary-treasurer. The name chosen for the new organization was the "International Association for the Prevention of Smoke."

At the same time, the Detroit *Free Press* reported the invention of a coal pulverizer and burner as well as the new group's formation. A demonstration of the new device, the brainchild of Benjamin J. Walker, of Erie, Pa., was lauded highly by the smoke inspectors who professed astonishment at its simplicity.

At the first meeting of the new organization, a resolution was adopted favoring regulation of smoke by state legislative action rather than just municipal ordinances. Each participating municipality also was asked to contribute toward the expenses of the Association.

Membership Restricted

A motion to permit other persons than inspectors to join the organization was defeated because the members felt that

railroads, stoker companies, and other potential enemies might attempt to seize control.

The officials in attendance agreed that a necessary step was to put the installation of furnaces and boilers under the supervision of a mechanical engineer. In that respect, Professor Kent of Syracuse (author of Kent's Mechanical Engineers' Handbook) urged the use of draft gauges, water meters, and records of the amount of coal used per hour for the operations. He asserted that the overfeeding of a boiler was the greatest evil possible in the creation of smoke.

By the time the seventh annual meeting was held in Pittsburgh, in 1913, the same three men, Mr. Poethke, Mr. Fairgrieve, and Mr. Harris, still held their officerships. John Krause, Cleveland smoke inspector, also was carried as a founder of the Association.

The Association's work was steadily gaining recognition because the Milwaukee *Sentinel* pointed out in its editorial columns: "Plausible arguments have been advanced to show that it is possible to attach mechanisms to boilers and fireboxes which will cure the (smoke) evil."

At the second annual meeting of the Association, in 1908 at Cleveland, Mr. Bird came out with a unique solution for the problem of locomotive smoke. He recommended the railroads switch from steam to electric power.

At the 1909 meeting of the association in Syracuse, H. M. Wilson quoted figures to the effect that smoke was causing $600,000,000 damage per year

in the United States. Mr. Wilson was chief engineer of the technologic branch of the U. S. Geological Survey, later known as the U. S. Bureau of Mines. Another speaker, Thomas H. Darlington, health commissioner of New York City, delivered harsh criticism at the problem with a paper, "Smoke as a Public Nuisance."

During the fourth annual meeting at Minneapolis, Mayor James C. Haynes made much of the opinion of Professor W. D. Marks that large cities would solve the smoke problem by confining the use of coal to a central gas plant. From it would come the light, heat, and power for the entire city.

Joseph Harrington, of Chicago, now deceased, read a paper on the "Harrington Automatic Stoker."

At the next annual meeting in Newark, N. J., the speakers included George Howaldt, of Berlin, Germany, and T. A. Marsh, Chicago, for many years a national industrial engineer with the Iron Fireman Manufacturing Co. A former member of Chicago's Smoke Abatement Commission, Mr. Marsh is still a consultant on smoke control and combustion in Lakewood, Ohio.

Another speaker was the late R. H. Fernald, consulting engineer for the U. S. Bureau of Mines, who talked about "Gas Producers." He later headed the mechanical engineering department at the University of Pennsylvania and was active in the ASME.

Railroad Day Started

The 1912 meeting was held at Indianapolis and the second day's session was noted as "Railroad Day," a custom that was followed for many years. Several papers were presented by railroad officials on the progress made in smoke control by their lines.

At the same time, Professor Joseph A. Beck of the University of Pittsburgh, told of the comprehensive investigation of the smoke problem undertaken by the Mellon Institute. Mr. Harris handed in his resignation as secretary-treasurer because of his appointment as commissioner of public works for the City of Toronto. He was replaced by Mr. Krause. Other officers elected included J. P. Brown, Indianapolis, president, and J. M. Searle, Pittsburgh, vice president.

Pittsburgh was the host for the 1913 meeting and the printed proceedings of it are the oldest in our files. William B. Smith, of Glasgow, Scotland, acting president of the West Scotland Branch of the Smoke Abatement League of Great Britain, talked about "The Abatement of Smoke on Two Continents: A British View."

The four-day conclave was occupied by only four papers, all of them receiving full discussion, particularly one on "Locomotive Smoke." Mr. Whelan, of Cleveland, delivered the paper in which he pointed out:

"I am glad to see the cooperation that exists between the city smoke inspectors and the railroads. I remember attending a convention of this body when I was the only railroad man there. And I heard a member of this Association make the remark that there is only one way to handle the railroad officials and that is with a hickory club. The suggestion did not set very well on me because I happened to be a railroad official at that time."

Mr. Whelan apparently was the first railroad man to participate in the meetings of the Association. He was with the Big Four Railroad, which was merged with the New York Central System, but when the job of railroad smoke inspector was created by all the railroads entering Cleveland, he was appointed and paid by the railroads on a cooperative basis. However, he reported directly to the Cleveland Smoke Commission daily, his reports receiving the same attention as those of the city inspectors. He also served as the liaison man between the city and railroads and did an outstanding job.

Membership Broadened

The meeting also saw the amendment of the by-laws to read as follows:

1 All persons of good moral character engaged in or who have past experience in scientific pursuits and all persons engaged or interested in or who have past experience in the prevention of smoke shall be eligible for active membership in this association.

2 Associate members shall be persons interested in the advancement of technical knowledge or pursuits but without actual experience by service in some one of the engineering or professional pursuits, and shall have all the rights of active members except that they shall not enjoy the right of elective franchise nor shall they hold office in this Association.

The 1914 meeting in Grand Rapids, Mich., saw five papers presented in three days. The speakers included Lloyd R. Stowe of St. Louis and Joseph W. Hays of Chicago, inventor of the Hays instruments and head of the Hays School of Combustion.

It was at this affair that the name of Osborn Monnett appeared for the first time. He was then chief smoke inspector for Chicago. The author of many works on smoke published by the Bureau of Mines, he also had charge of the Salt Lake City investigation and later acted as consulting engineer for the Citizens Smoke Abatement League of St. Louis.

The convention program carried the pictures of 33 delegates, including the late William Burrows, road foreman of engines for the Terminal Railroad of St. Louis, and for several years chairman of the Railroad Smoke Abatement Committee of St. Louis.

The officers were listed as: Louis C. Towner, president, Grand Rapids; William A. Hoffman, vice president, St. Louis; and S. H. Viall, secretary-treasurer, Chicago.

Chairmen of the committees were O. Monnett, publicity; Frank A. Chambers, standardization; and J. W. Henderson, ways and means.

The 1915 meeting took place in Cincinnati September 8–10 and 50 of the Association's 60 members were present. The agenda included 13 technical papers, including seven general ones and four concerning the railroads' problems. The marine smoke problem was tackled for the first time with a

paper on "Smoke Abatement on Lake and River Steamboats." Another first was a paper on "Smokeless Combustion as Applied to Clay Products Plants."

Joe Harrington contributed a paper again which was discussed at length by William Mittendorf, an engineer for a large coal producer at Cincinnati. Mr. Mittendorf, before his death, took an active role in many of the Association's later meetings as well as in the affairs of the ASME Fuels Division.

Name Changed

There was a successful move to change the name to Smoke Prevention Association and qualifications for membership in the growing group were changed to admit "Any person interested in the objects of this Association." Dues were set at $5 per year.

The Association's fiscal affairs still hadn't reached important proportions. The Auditing Committee's report showed:

Receipts from Dues	$170.00
Receipts from Advertising	$228.00
Interest on Money in Bank	14.78
Total Receipts	$412.78

The Standardization Committee's recommendations for organizing committee operations along more efficient lines were adopted.

The new officers were announced as: William A. Hoffman, St. Louis smoke inspector, president; Charles W. Heath, Cincinnati smoke inspector, vice president; and Frank A. Chambers, Chicago mechanical engineer, secretary-treasurer.

St. Louis was the scene for the 1916 annual meeting. There were 12 papers for presentation but the proceedings this time included elaborate illustrations, tables, and graphs.

Martin A. Rooney, chairman of the Standardization Committee, suggested that the Association sponsor nationally a Clean Air Week in order to publicize the Association's work. Mr. Rooney was chief smoke inspector of Nashville, Tenn.

The constitution was amended to provide for a second vice president and, until 1949, it was the custom to elect a railroad man to the post. A Railroad Committee also was appointed.

The speakers' list included E. R. Fish, who presented a work on "Draft." He was vice president of the Heine Safety Boiler Co. and later was with the Combustion Engineering Co. and then the Hartford Boiler Inspection and Insurance Co. as chief engineer. He also is a former manager and vice president of ASME.

The officers elected that year for the first time included men who weren't smoke inspectors for cities. The list read: William H. Reid, chief smoke inspector, Chicago, president; Martin A. Rooney, chief smoke inspector, Nashville, first vice president; W. L. Robinson, fuel supervisor, Baltimore and Ohio Railroad, second vice president; and Frank A. Chambers, mechanical engineer, secretary-treasurer.

Railroads Active

The delegates to the early meetings of the Association apparently were asked to sign their names in a record book. The book for this 1916 meeting in St. Louis is still preserved in the Association's files and shows the names of 97 men, of which 37 indicated they were associated with railroads rather than with municipalities.

The second name on the list is that of J. W. Burrows, who was mentioned earlier as road foreman of engines for the Terminal Railroad Association of

St. Louis. The late Mr. Burrows guided smoke control for the railroads there and was the first chairman of the Railroad Smoke Abatement Committee in St. Louis, organized in 1921. He was chairman several years.

Another railroad man, Martin Whelan, of Cleveland, was in attendance with his wife and daughter. The list also included the names of such distinguished authorities as: Lloyd R. Stowe, manager of the stoker department for Laclede-Christy Co.; Eugene P. Bradley, who was in partnership with Tom Hester as distributors for the Kewanee Boiler Co.; J. F. McIntire, who became vice president of U. S. Radiator Co.; John Nooter, a boiler manufacturer of St. Louis, and Thomas Wilson, western editor of *Power* magazine, Chicago.

World War I was in progress when the Association held its 1917 meeting, Sept. 25–27, in Columbus, Ohio.

With President William H. Reid of Chicago in the chair, a resolution was adopted pointing to the importance of fuel conservation and calling on the Federal Government to appoint a Fuel Conservator in each state. The resolution also offered the services of the members of SPA as combustion experts.

Also adopted was a long report from the Standardization Committee proposing standards on many items such as furnace volume, stoker setting heights, boilers, chimney sizes, and heights.

The same officers were re-elected with the exception that W. H. Corbett went in the post of second vice president. And the records show that the secretary-treasurer's salary was raised to $200 per year and Louis H. Towner, a past president, was made an honorary member.

Among the papers presented at the session were: "Proportioning of Chimneys on a Fuel Basis," by Henry Misostow, mechanical engineer of the Chicago Smoke Department; "Smokeless Combustion of Coal," by R. L. Beers, of the Detroit Stoker Co.; "General Utilization of Pulverized Coal," by H. G. Barnhurst, chief engineer of the Fuller Engineering Co. at Allentown, Pa.

The 1918 meeting in Newark, N. J., Aug. 20–23, resulted in the election of the following officers: Warren Edson, Boston, Mass., president; W. H. Corbett, Niles, Mich., first vice president; W. A. Pittsford, Chicago, second vice president; and Frank A. Chambers, Chicago, secretary-treasurer.

It was resolved to present exhibits at the next annual meeting, in Chicago, for which the secretary was to set the date. However, the records do not show that a meeting was held in 1919.

Association Grows

The 1920 meeting was held in Chicago, Oct. 5–8, and it turned out to be the biggest one to date. The record book shows 131 registrations.

The names included those of G. F. Gebhardt, of Chicago, believed to have been the author of a hand book on power plants, and T. G. Thurston, editor of the "National Engineer," and E. V. Hill, of the Chicago Health Department, who is believed to have been the inventor of the Hill Dust Counter.

And for the first time the names of Frank E. Trumbull and Gordon D. Rowe, chief smoke inspectors respectively at Buffalo and Cleveland, appeared on the records. Both remained active in smoke control work for years and Mr. Trumbull became president of the Association.

An inflationary note was seen in the increasing of the secretary-treasurer's salary from $200 to $300. The election resulted in the following list of officers: Joseph M. Lonergan, chief sanitary inspector of the Health Department of New York City, president; W. A. Pittsford, Chicago, first vice president; J. W. Burrows, St. Louis, second vice president; and secretary-treasurer, again Mr. Chambers.

At the 1921 meeting in St. Louis, May 31–June 3, the Association voted to create a publicity committee to obtain more members from different cities, and to establish a clearing house for information on smoke prevention.

The Public Service Committee was established and it set up the Central

Information Bureau. The Committee was authorized to solicit necessary funds and collect and tabulate data on smoke prevention for distribution to cities desiring information on the subject.

A paper that drew a great deal of interest was presented by Dr. E. L. Opie, Washington University Medical School, St. Louis, on "Effect of Smoke on Health."

The 1922 meeting was staged in Cleveland, June 13–16, and the welcoming address was given by Col. E. H. Whitlock, chairman of the Smoke Abatement Committee of the Cleveland Chamber of Commerce. The late Colonel Whitlock was subsequently Smoke Commissioner of Cleveland for several years and later had charge of Smoke Abatement Research at Stevens Institute of Technology, Hoboken, N. J.

Nation Awakens

The report of the Public Service Committee showed that the nation was becoming smoke control conscious. C. D. Behan, publicity director, reported the committee had distributed 7500 copies of the health article which had been presented by Dr. Opie at the 1921 meeting. Newspaper publicity was ample and numerous inquiries regarding smoke ordinances had come in from all over the country. It was also noted that Association members had given talks before many organizations.

Women's clubs were beginning to take active interest in the Association's work and numerous representatives were present for the meeting. The speakers included Judge Florence E. Allen, Cleveland, one of the first women ever appointed to the bench.

Officers elected were F. E. Reidhead, Grand Rapids, Mich., president; F. G. Rogers, Chicago, first vice president; E. J. Summers, second vice president; and Mr. Chambers, secretary-treasurer.

A comprehensive article, "What Is at the Bottom of a Smoking Stack?" was presented by Mr. Chambers.

A large part of the meeting was occupied with the announcement of the smoke control ordinances of the following cities: Chicago, Boston, Cleveland, Cincinnati, Omaha, Denver, Detroit, Minneapolis, Pittsburgh, Des Moines, Harrisburg, Columbus, Toronto, Montreal, New Orleans, Los Angeles, St. Paul, New York, Philadelphia, Salt Lake City, Duluth, Newark, Grand Rapids, Nashville, Milwaukee, Kansas City, Rochester, and Indianapolis.

Association Incorporated

It was during the 1923 meeting at Minneapolis, June 19–22, that the Association was incorporated. The officers were Mr. Reidhead, president; Mr. Pittsford, vice president; Thomas Hagerty, second vice president, and Mr. Chambers, secretary-treasurer.

The Public Service Committee took up the suggestion of George W. Bach, president of the American Boiler Manufacturer's Association, that his group and the Association get together on establishing furnace heights and boiler settings.

At the 1924 meeting in Buffalo, June 3–5, the following officers were elected: H. B. Miller, chief of the Bureau of Smoke Regulation at Pittsburgh, president; J. W. McNeal, Chicago Down Draft Furnace Co., first vice president; and Mr. Chambers, secretary-treasurer.

Mr. Bach, of Erie, again spoke in favor of the Association and the boiler manufacturers setting up standards for the field.

Smoke Ordinance Planned

After a discussion of the smoke ordinance recently issued by the ASME, the Association authorized the preparation of one for its own purposes.

The proceedings of the meeting were combined into a manual which became an annual publication. Smoke ordinances in many cities were quoted in it and it also contained the report of the Standardization Committee with elaborate codes on various types of equipment.

The manual also listed the men in charge of smoke prevention in a number of cities and a list of railroad officers in charge of smoke abatement. The names included those of George H. West, New York Central Lines, Buffalo, and George G. Ritchie, Chesapeake and Ohio Railroad, Richmond, Va.

The names for the city officials included Gordon D. Rowe, veteran Cincinnati inspector, and Robert H. Karl, St. Louis. Mr. Karl, who was formerly chief engineer of the Anhauser-Busch Brewing Co., passed away shortly after the manual was published.

The 1925 meeting was held at Grand Rapids, June 17–20, but unfortunately the proceedings of the meeting could not be located. The Association does have, however, a manual and yearbook which show that the officers elected were: William R. Supple, chief of Mechanical Bureau, Buffalo, president; M. A. Rooney, American Radiator Co., Buffalo, first vice president; Thomas Finn, chief smoke inspector Pennsylvania Railroad Lines, West Chicago, second vice president; and Mr. Chambers, secretary-treasurer.

The officers elected at the 1926 meeting in Milwaukee, June 28–30, were: G. M. Jewell, chief smoke inspector, Grand Rapids, president; C. Folsen, Kewanee Boiler Co., first vice president; W. B. Combs, traveling engineer, Belt Railroad, Clearing, Ill., second vice president; and Mr. Chambers, secretary-treasurer.

The yearbook listed for the first time the name of Col. E. H. Whitlock as commissioner of Smoke Regulations for Cleveland. John H. Lewis, retired official of the Burlington Railroad, was made an honorary member of the Association.

Mr. Lewis told how he had joined the Association 16 years before (1910) when there were only 12 members. He said that a Mr. McDonald of Toronto was the secretary-treasurer, but the Association's meager records for that period

don't show the name. He also mentioned that those attending the 1910 meeting had to chip in to pay the expenses.

Charles Poethke, of Milwaukee, also went on the honorary membership list.

A committee of five members was appointed to investigate new locomotive devices, determine their merit, and report on their success relative to smoke elimination.

The 1927 meeting in Des Moines, Iowa, June 27–29, saw a total of 19 papers presented and the election of the following officers: H. J. Glascott, Buffalo, president; Thomas Casserly, research engineer, Weil McLain Co., Michigan City, Ind., first vice president; A. C. Stockwell, New York Central Railroad, Chicago, second vice president; and Mr. Chambers, secretary-treasurer.

This was the first meeting at which the Entertainment and the Ladies Entertainment Committees functioned. M. A. Rooney, of Buffalo, headed the first committee and Mrs. Andrew Gillman, of Rochester, was chairman of the Ladies Entertainment Committee.

At the 1928 meeting in Rochester, one of the 19 papers presented was by the late A. A. Raymond, superintendent of Locomotive Performance for the New York Central Lines. J. B. Hurley, general Road Foreman of the Wabash Railroad, Decatur, Ill., talked extensively on the progress of the Association, with which he had been associated many years. He also played a leading role in the work of the Railroad Smoke Committee at St. Louis.

W. H. Corbett and Daniel Maloney were elected honorary members.

Elected as officers, including for the first time a sergeant-at-arms, were: A. J. Glascott, Buffalo, president; Thomas Casserly, Michigan City, Ind., first vice president; J. H. Rewald, Chicago, second vice president; Mr. Chambers, secretary - treasurer; and

George T. Beck, Chicago, sergeant-at-arms.

The officers elected at the 1929 meeting in Kansas City, May 14–17 were: G. M. Jewell, Grand Rapids, president; T. D. Casserly, Michigan City, Ind., first vice president; George T. Beck, Chicago, second vice president; Mr. Chambers, secretary - treasurer; and E. R. Kelly, sergeant-at-arms.

E. J. Summers went on the honorary member list.

The largest attendance in the history of the Association turned out for Railroad Day, when eight papers on the subject were presented.

One of the speakers was the late Osborn Monnett, consulting engineer of the Citizens Smoke Abatement League at St. Louis. His paper was entitled, "The Smoke Situation in St. Louis."

The Association's files do not contain the proceedings of the annual meetings in 1930 and 1931. However, we do have a manual of Smoke and Boiler Ordinances and Requirements which is marked as the official publication for the Association for that two-year period.

Among the names of the smoke abatement officials appearing in it for the first time were H. K. Kugel, smoke commissioner of Cleveland, and William G. Christy, Hudson, N. J.

The manual listed the following officers for 1931–32: J. J. Fitzgerald, Springfield, Mass., president; L. G. Plant, Chicago, first vice president; Herbert Dunn, Chicago, second vice president; Mr. Chambers, secretary-treasurer; and George T. Beck, sergeant-at-arms.

The manual listed 25 papers read at the 1930 meeting, June 24–26, at Newark, N. J. One of the speakers was H. H. Bubar, at that time associated with Dust Recovery Inc., New York City. Considered one of the top authorities in the country on dust and dust control, Mr. Bubar's paper was entitled, "Recovery of Dust and Fly Ash From Chimney Gases."

Another paper, "Smokeless Operation of Plants Using Low Volatile Coal," was given by W. E. E. Koepler, secretary of the Pocohontas Coal Operators Association at Bluefield, W. Va. The late Mr. Koepler served our Association for many years as vice president.

Another paper generating a lot of interest was "Hazards in Airport Due to Smoke" by Lt. R. Aldworth, superintendent of the Newark Airport. This was the first time that the advent of the air age and its relation to the smoke problem was recorded in the Association's files.

Goes International

The Association moved onto a concrete international footing in 1932 by holding its annual meeting in Toronto, Can., June 7–10.

In addition to the usual technical papers—five general and nine on railroads—there was a symposium on smoke abatement with many of the inspectors speaking directly from their personal experience and knowledge in the field.

The officers elected were: F. E. Trumbull, chief smoke inspector, Buffalo, president; L. G. Plant, Railway Engineering Equipment Co., Chicago, first vice president; E. R. Kelly, Illinois Northern Railroad, Chicago, second vice president; Mr. Chambers, secretary-treasurer; and N. E. Newburg, Michigan Central Railroad, Chicago, sergeant-at-arms.

Chicago History Reviewed

The 1933 meeting in Chicago brought a brief review of the history of smoke control in that city, the first in America to conduct an all-out campaign against the nuisance and health menace.

The first speaker was Thomas E. Donnelley, president of R. R. Donnelley & Sons Co. and first chairman of the Chicago Smoke Abatement Commission.

When Mr. Donnelley first became interested in the subject, Chicago's chief smoke inspector was a florist—a good florist but a very poor smoke inspector, according to Mr. Donnelley.

So poor, as a matter of fact, that a committee of the City Club, of which Mr. Donnelley was the chairman, brought charges against the inspector for malfeasance in office because smoke was billowing over the city the same as ever.

As Mr. Donnelley ruefully recalled it, the procedure for a person or firm accused of creating a smoke nuisance was to (1) resort to "political pull" or (2) turn the case over to the coal company, which would "persuade" the smoke inspector that the plant wasn't smoking up things at all. That ended the prosecution.

The picture changed in 1907 when Fred Busse was elected mayor and he in turn appointed the Smoke Commission, with full powers to handle the problem.

The commission, with Mr. Donnelley as chairman, persuaded Paul Bird, chief engineer of Illinois Steel Works, then the largest steel plant in Chicago, to take the inspector's job. Thus was born the first Smoke Regulation Department organized on an engineering basis. The new ordinances adopted at that time included the proviso that the chief smoke inspector and his assistant must be graduate engineers. All department employees but the chief inspector were put under the protection of Civil Service, and an advisory board of three prominent consulting engineers was appointed.

Mr. Bird resigned after four years and Osborn Monnett was appointed to the post. But when William Thompson was elected mayor in 1915, one of his first steps was to install a dentist as chief smoke inspector. Fortunately, the other employees were retained because of their Civil Service protection.

Mr. Donnelley paid tribute to Frank Chambers, veteran secretary-treasurer of the Association, and his colleagues for their courage in keeping smoke control on a strict engineering basis during those trying times.

Another speaker, Joseph Harrington, member of Chicago's Advisory Board, called attention to the fact that much smoke in Chicago originated outside the city. For that reason, he asserted, any effective control program would have to extend over a much larger area.

The meeting's agenda included 17 technical papers and, for the first time, the program listed the names of several men who discussed the papers. Among them was the late Henry Kreisinger, one of the country's leading combustion engineers as well as an authority on the burning of pulverized coal. He discussed the paper concerned with the "Elimination of Fly Ash."

In response to a letter from C. B. LePage, of the ASME, Frank Chambers was appointed to serve on that organization's Pure Air Committee.

Election of officers resulted in the return of Mr. Trumbull as president and Mr. Plant as first vice president. Mr. Chambers, of course, was re-instated as secretary-treasurer. J. P. Morris, Santa Fe Railroad, Chicago, was elected second vice president and A. Pitt, C & NW Railway, Chicago, as sergeant-at-arms.

The 1934 annual meeting was held at Buffalo, July 19–21, and 16 papers were presented, one of them by the late Osborn Monnett who was then in charge of a smoke abatement investigation in Chicago, financed by the C. W. A. Mr. Monnett discussed the project in which 150 engineers were participating.

An editorial published in *Power*, which many of those present thought cast aspersions on the work of the Association, brought on a discussion that resulted in a motion that the Resolution Committee be asked to answer the criticism.

Mr. Trumbull was re-elected president and Mr. Chambers as secretary-treasurer. New officers were W. E. E. Koepler, secretary of the Pocohontas Operators Association, Bluefield, W. Va., first vice president; W. A. Langlands, C & NW Railway, Chicago, second vice

president, and H. V. Carlson, Nickel Plate Railroad, Chicago, sergeant-at-arms.

The Association manual for the meeting contains the Standard Smoke Ordinance which was recommended by the Public Service Committee. The manual also contains the answers received to an extensive questionnaire which the secretary had sent to the various cities, counties, and other smoke abatement districts in this country and Canada.

Twenty technical papers were presented at the 1935 meeting in St. Louis, June 4–7.

Educational Sessions Planned

A big and new feature of the meeting was the Evening Educational Sessions. The first evening session was designed for power engineers, superintendents, and plant managers. The second was for coal dealers, merchants, and mine operators. The third was for railroad officials, engineers, firemen, foremen, shopmen, and other railroad employees, and the fourth was arranged for real estate agents, dealers, industrial officials, home, and apartment owners. These evening sessions and exhibits drew good attendance.

The business meeting resulted in a resolution of sympathy in the death of J. B. Hurley, general road foreman for the Wabash Railroad, who was chairman of the Railroad Smoke Abatement Committee of St. Louis and extremely active in this Association.

Federal Aid Sought

A second resolution urged the Association to seek federal financial aid in carrying out air pollution control programs. Another resolution authorized the offer of assistance and cooperation to the ASME in preparing a model smoke law.

Other resolutions called on Congress to give serious consideration to the smoke problem in the nation's capital, and authorized appointment of a committee to investigate and create a standardized system for measuring air pollution. It also was to be recommended for adoption in various cities.

Officers elected were: J. D. Bryan, St. Louis smoke commissioner, president; W. E. E. Koepler, first vice president; J. D. Clark, Richmond, Va.; second vice president; Mr. Chambers, secretary-treasurer; and James Powers, sergeant-at-arms.

Among the 17 papers presented at the 1936 meeting in Atlanta, Ga., June 2–5, was a comprehensive one, "Atmospheric Pollution in American Cities," by Dr. R. R. Sayers, senior surgeon, and James E. Ives, Sr., physicist, U. S. Public Health Service.

The work described the investigation of atmospheric pollution in 14 cities and explained the various instruments used in taking the large number of readings. The results were judged as highly informative and the complete report was published in Public Health Bulletin No. 224.

The record also contained the announcement and program of the "Century of Coal Burning Progress Exposition" that was held in Atlanta's City Auditorium, May 25–June 6.

Atlanta's mayor proclaimed Smoke Abatement Week for the city while the SPA was holding its meeting. Several news articles and editorials from the local papers also were entered into the proceedings.

The business meeting brought a resolution reaffirming the Association's request for assistance from the government in a study of air pollution.

The officers elected were: J. D. Bryan, president; W. E. E. Koepler, first vice president; W. C. Shove, New York New Haven & Hartford Railroad, New Haven, Conn., second vice president; Mr. Chambers, secretary-treasurer, and A. W. Jones, Atlanta smoke inspector, sergeant-at-arms.

The 1937 meeting took place in both New York City and Hoboken, N. J.

The principal welcoming address was given by Dr. J. L. Rice, New York's health commissioner. Also speaking were Sol Pincus, deputy health commissioner; William G. Christy, Hudson County, N. J., and W. E. E. Koepler, who was described as the "roving ambassador" for the SPA.

H. D. Blackwell, listed as the SPA's educational director, discussed the exhibits which were provided by the U. S. Bureau of Mines, the U. S. Public Health Service, U. S. Weather Bureau, and the W. P. A. Air Pollution Survey in New York.

June 2 was designated as Hudson County Day. The day's sessions were held in the Auditorium of the Stevens Institute of Technology at Hoboken. The welcoming address was made by the late Dr. Harvey N. Davis, president of Stevens and chairman of the Advisory Board of the Hudson County Smoke Regulation Department. All of the papers that day were devoted to the comprehensive smoke control work being carried on in Hudson County. Representatives of the Railroad, Marine, and Industrial Smoke Abatement Associations told about their projects.

The late Professor Frank of Stevens gave an interesting paper describing the air pollution measurement work being carried on by Stevens in cooperation with the Weather Bureau.

John L. Hodges, then Hudson County deputy and now director of Smoke Control in Cleveland, presented a paper summing up the program in Hudson County.

Back at the Pennsylvania (Statler) Hotel, H. K. Kugel, smoke regulation engineer in Washington, D. C., gave a paper entitled "Inaugurating a New Division of Smoke Regulation in the District of Columbia." A report on the New York Air Pollution Survey was given by Arthur C. Stern, who was in charge of the W. P. A. project and who now is chief of the Air Pollution Control Program of the U. S. Public Health Service.

J. F. Barkley of the Bureau of Mines contributed a paper on "Smoke and Fly Ash Prevention at the Federal Central Heating Plant." A study on "Atmospheric Pollution in Chicago" was presented by Dr. A. D. Singh, of the Engineering Experiment Station of the University of Illinois, and Frank A. Chambers and I. A. Deutch of the Chicago Smoke Department. This covered the investigation of SO_3 and contained the results of nearly 300 analyses of the atmosphere for SO_2 in numerous industrial, railroad, business, and residential districts in Chicago.

Mr. Whalen of St. Louis, an honorary member of the Association, spoke on the railroads' work.

A resolution of sympathy was adopted on the death of Martin Whelan of Cleveland at the age of 80. Mr. Chambers stated that Mr. Whelan, an honorary member, probably had attended every annual meeting except the previous one.

Study Suggested

The Standardization Committee's report, covering 45 pages, included a suggested study for adoption of standards relating to the methods of measuring and testing air pollution.

The program discloses that the Association now had a Membership Committee, which suggested that registration cards be used at all future meetings.

The election resulted in the following officers: William Culbert, chief smoke inspector of Nashville, Tenn., president; Mr. Koepler, first vice president; J. M. Whalen, master mechanic of the Missouri Pacific Railroad, St. Louis, second vice president; Mr. Chambers, secretary-treasurer; and C. L. Goodwin, Chicago, sergeant-at-arms.

The proceedings contained a news item showing that Federal Court had upheld the new St. Louis Smoke Ordinance. This was a revised ordinance requiring the use of low volatile coal, and some of the Illinois coal operators had battled the ordinance up to the government's courts.

The 1938 meeting was held in Nashville, Tenn., May 17–20. The 19 papers presented included "New Features in Smoke Abatement Legislation"

by R. R. Tucker, then smoke commissioner of St. Louis and now its mayor. Harry M. Pier of Research Corp., now recently retired executive secretary of APCA, presented "Removing Solids From Gases."

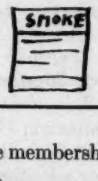
For the first time the proceedings contained two papers which had been presented at the Smoke Inspectors Conference.

Edward C. Loye of Milwaukee brought greetings from Charles Poethke, one of the two living charter members of the Association.

The officers elected were: William Culbert, president; S. C. Higgins, secretary of the New River Coal Operators Association, Mt. Hope, W. Va., first vice president; H. V. Carlson, second vice president; Mr. Chambers, secretary-treasurer; and H. Keyes, Chicago Milwaukee & St. Paul Railroad, Oak Park, Ill., sergeant-at-arms.

Milwaukee was host for the 1939 meeting, June 13–16. The 17 papers included "Report on Combustion Space Survey" by Ralph A. Sherman and R. C. Cross of Battelle Memorial Institute, Columbus. This was a comprehensive report with much detailed data. The record also shows two papers which were presented at a meeting of the Standardization Committee.

The Association's new bulletin, *Smoke*, which was being sent out



monthly to the membership, drew favorable comment.

John F. Barkley of the Bureau of Mines, who had presented several papers and otherwise taken an active role, was made an honorary member. The Association also sent a resolution of thanks to the sponsors of the Combustion Space Survey which included stoker, coal, and boiler industry authorities.

Elected officers were: Reinhard Kunz, Milwaukee's chief smoke inspector, president; George G. Ritchie, Fuel Service Engineer of Chesapeake and Ohio Railroad, first vice president; John Benschip, Pennsylvania Railroad, Chicago, second vice president; Mr. Chambers, secretary-treasurer; and Paul Miller, Chicago, sergeant-at-arms.

Charles Poethke, then chief assistant in Milwaukee's Smoke Department, was introduced as the only living charter member of the Association.

There was considerable discussion of a motion made to change the name of the Association to the Smoke Prevention Association of America. George Ritchie pointed out that the Association at one time was known as the National Smoke Prevention Association. Other names suggested included International Smoke Prevention Association, National Air Pollution and Smoke Prevention Association of America, and the Air Pollution and Smoke Abatement Association. Finally a substitute motion was adopted which recommended that the Executive Committee study the matter and report at the next annual meeting.

The 1940 meeting was held at St. Louis, May 21–24, and 18 technical papers were presented.

A whole session was devoted to a general discussion of "Railroad Locomotive Smoke Abatement," as outlined by William G. Christy.

R. R. Tucker, St. Louis Smoke Commissioner, reported on that city's new smoke ordinance, the one requiring the use of low volatile coal for hand firing.

Five speakers participated in a panel discussion of different firing methods. An interesting paper on "Atmospheric Corrosion" was presented by Professor H. Kuenzel of the Mechanical Engineering Department of Washington University at St. Louis. This covered an investigation and tests which pointed up the corrosive problem created by air pollution.

Charles Gruber, of Cincinnati, chairman of the Membership Committee, outlined various items that were being used to build up interest and membership in the Association.

The Standardization Committee reported the ASME had drawn up a code for determining dust concentration and tests for rating the efficiency of dust collectors. The committee also reported upon its own work on dust concentration and methods of measuring dust loadings. They also announced they were continuing their study of combustion space requirements and methods of measuring smoke density.

Name Changed Again

After Secretary F. A. Chambers reported the Executive Committee had recommended the Association adopt the new name Smoke Prevention Association of America, a motion was passed to that effect. Mr. Chambers explained that in the past, when the Association was known as the National Smoke Prevention Association, the word "National" had been omitted after Canada began active participation.

John Barkley suggested that members send in their ideas for an emblem for the organization.

A resolution also was passed that made the Smoke Inspectors Conference a regular part of the program each year.

Officers elected were: Reinhard Kunz, president; W. E. E. Koepler, first vice president; W. C. Newburg, Michigan Central Railroad, Chicago, second vice president; Mr. Chambers, secretary-treasurer; and F. A. Cutter, Chicago & Northwest Railroad, Milwaukee, sergeant-at-arms.

Helps in War Effort

War clouds were beginning to darken the sky as the SPAA held its 1941 meeting at Atlanta, Ga., June 3–6.

But it wasn't until the following year that the APCA threw its full weight into the effort to conserve coal as the nation engaged in the worldwide struggle.

Minutes of the 1941 meeting show that a Ladies Auxiliary was in operation. It apparently had been formed the year before.

The records also show an elaborate report on "Abating Locomotive Smoke in Chicago" by I. A. Deutch and Sam Radner of the Chicago Smoke Department.

Elected as officers for the forthcoming year were: H. K. Kugel, Washington, D. C., president; W. E. E. Koepler, first vice president; S. T. Peters, Grand Trunk Railroad, Chicago, second vice president; Mr. Chambers, secretary-treasurer; and A. W. Jones, Atlanta smoke inspector, sergeant-at-arms.

The war moved into the forefront as the Association held its 1942 meeting in Cleveland, O., June 2–5.

Thomas J. Thomas, of the Office of Fuel Coordination, Washington, talked about "Coal—Its Relation to the War."

Professor Sumner B. Ely, formerly of Carnegie Institute of Technology, presented a paper on "Smoke Abatement in Wartime." Professor Ely had retired from the school a short time before to head Pittsburgh's newly-revised Smoke Bureau in 1941.

A resolution of appreciation was adopted to thank Dr. H. B. Meller of Pittsburgh for his valuable contributions to smoke control. Another resolution sent greetings to the Brotherhood of Locomotive Engineers which was meeting at the same time in Cleveland.

During a later session, J. Harkins, assistant grand chief of the Brotherhood, addressed the Association and assured the members of the cooperation of his organization.

Inspectors Meet

For the first time the proceedings carried a brief account of the smoke inspectors conference. The conference was addressed by J. F. Barkley on "How Smoke Regulation Departments Can Assist in the War Project of Control, Allotment and Conservation of Coal."

Officers elected were: A. E. Hutchinson, smoke abatement engineer of Cleveland, president; W. E. E. Koepler, first vice president; G. P. Kenworthy, Wabash Railroad, Decatur, Ill., second vice president; Mr. Chambers, secretary-treasurer; and W. H. Dempsey,

Chicago Milwaukee & St. Paul Railroad, Milwaukee, sergeant-at-arms

At the 1943 meeting in Pittsburgh, June 8–11, all of the officers were re-elected to their posts with the exception of Mr. Kenworthy, who was replaced in the second vice presidency by J. E. Cooney, Atcheson Topeka & Santa Fe Railway, Chicago.

There were 13 papers on general subjects and three on railroads.

The 1944 meeting at Detroit, June 6–9, was marked with the presentation of 26 papers, 21 on general subjects and five concerned with railroads.

Elected to office were: Ernest B. Brundage, chief smoke inspector at Rochester, N. Y., president; W. E. E. Koepler, first vice president; Walter Scott, Chicago & Northwest Railroad, Chicago, second vice president; Mr. Chambers, secretary-treasurer; and Harry Keech, Pennsylvania Railroad, Cleveland, sergeant-at-arms.

The 1945 annual meeting, at Columbus, Ohio, wasn't held until Oct. 16 because of the Government's ban on conventions during the war.

Secretary Chambers read a resolution of warm appreciation received from the National Smoke Abatement Society of Great Britain. Mr. Chambers explained that it had come in answer to the resolution of the previous year in which the Association had congratulated the Society for carrying on its work without interruption during the trying conditions of the war. In the ensuing discussion it was decided to invite Arnold Marsh, executive director of the British Society, to participate in future meetings of our Association.

Weather Bureau Invited

An invitation was extended to the U. S. Weather Bureau to participate in an extensive study aimed at the adoption of standard methods for measurements of the extent of atmospheric pollution.

Along with 11 technical papers there were two general symposiums. Although no record of officers can be found, it was ascertained that Mr. Brundage was re-elected president and Mr. Koepler and Mr. Chambers were returned to their respective posts as first vice president and secretary-treasurer.

During the 1946 meeting at Minneapolis, June 26–28, Chairman Frank Chambers reported the Standardization Committee was confining its efforts to these four objectives:

1. Obtaining the cooperation of the Weather Bureau in standardizing air pollution measurement methods.
2. Standardization of combustion equipment.
3. Securing standardized effort in connection with installation and operation of incinerators.
4. Setting up standards of dust emission.

The 14 papers presented included a reprint of "Air Supply to Railroad Locomotive Boilers," which had been presented by members of the staff of Battelle Memorial Institute at the annual meeting of the ASME

The office of Director of Public Relations was created and the first man elected to the post was W. E. E. Koepler.

Other officers elected included: Professor Sumner B. Ely, Pittsburgh, president; E. D. Benton, Ohio Coal Bureau, first vice president; C. J. Sokel, Clearing, Ill., second vice president; Mr. Chambers, secretary-treasurer, and G. C. Hess, Pennsylvania Railroad, Jersey City, sergeant-at-arms.

The following names appeared for the first time on the list of city, county, and state officials in charge of smoke regulation: J. H. Carter, St. Louis; H. E. Kunkel, Los Angeles; F. W. Classon, Wyandotte, Mich.; W. L. Butler, Salt Lake City; J. J. Kelly, Alexandria, Va.; L. J. Cudbird, Toronto, Can.; and F. J. Gibbons, Detroit.

At the 1947 meeting in Toronto, July 7–10, additional names on this list included: Dr. L. C. McCabe, Los Angeles County; T. A. Podolske, Minn.; A. E. Robinson, Kansas City; John J. Ryan, Jr., New York City; H. G. Dyktor, Cleveland; Eli May, Erie; T. C. Wurts, Allegheny County, Pa.; and C. S. Frost, Roanoke, Va.

The proceedings contained 13 papers on general subjects and there were 10 on railroads. The business session included a preliminary report by J. H. Carter, chairman of the Committee on Standards for Dust Emission.

Dan Sullivan, chairman of the Membership Committee, reported a large increase and announced he had written letters to some 100 mayors in the United States and Canada, inviting them to have their smoke control officials participate in the work of the Association.

Elected to office were: Professor S. B. Ely, president; M. W. Crew, Milwaukee, first vice president; C. G. Wilcox, Pennsylvania Railroad, Baltimore, second vice president; Mr. Chambers, secretary-treasurer; W. E. E. Koepler, director of public relations; and T. J. Kubal, Milwaukee.

The entertainment highlight of the convention was an elaborate luncheon given by the City of Toronto at the Royal Canadian Yacht Club, located on

an island in Toronto Harbor. The members, including the women in attendance, spent a good part of the afternoon on the spacious club grounds.

The 1948 meeting at New York City, June 7–10, opened with a luncheon address by Dr. H. S. Mustard, health commissioner of the city.

Association membership was reported at 235 but there were 256 men and 100 women registered for the meeting.

Constitution Studied

The incoming president was authorized to appoint a five-member committee to study the desirability of amendments to the constitution and revisions to the by-laws, with a report to be presented at the next annual meeting.

Another resolution made the Smoke Inspectors Conference a permanent part of the annual meetings, with at least a half-day to be devoted to the session.

It was also decided to try to provide funds to help the Weather Bureau determine the factors that affect the concentration and dispersal of atmospheric pollution. A Meteorological Committee was appointed with Dr. Louis C. McCabe as chairman.

Frank Chambers of the Standardization Committee announced the appointment of three sub-committees as follows: J. H. Carter, St. Louis, chairman of Standards for Emission of Solids and Chimney Gases; M. W. Crew, Milwaukee, chairman of Combustion Equipment; and H. E. Kunkel, Los Angeles, chairman of Fumes, Vapors, and Noxious Gases.

William G. Christy, chairman of the Program Committee, reported that the new plan, whereby authors of papers were asked to submit them six weeks in advance, had been only partially successful. It was hoped, however, that papers in the future would be submitted in time to have them duplicated prior to the meeting.

A written ballot resulted in the choice of Birmingham as the next meeting site.

Meanwhile, President Christy appointed T. C. Wurts chairman of a special committee to draw up a new constitution and by-laws for presentation to the Executive Committee before the Birmingham meeting.

Other members of the committee were: H. C. Ballman, Columbus; H. G. Dyktor, Cleveland; Prof. S. B. Ely, Pittsburgh; C. W. Gruber, Cincinnati; H. F. Hebley, Pittsburgh; H. K. Kugel, Washington; and R. L. Wolf, Indianapolis.

President Christy also appointed a Nominating Committee to examine the qualifications of nominees before election time at the annual meetings. H. K. Kugel was named chairman.

The 1948 meeting ended with the election of the following officers: William G. Christy, Hudson County, N. J., president; W. E. E. Koepler, first vice president; A. A. Raymond,

New York Central Railroad, Buffalo, second vice president; Mr. Chambers, secretary-treasurer; D. A. Sullivan, Chicago, director of public relations; and Thomas P. Scully, Chicago, sergeant-at-arms.

Storm Warnings Gather

The 1949 meeting at Birmingham, May 23–27, resulted in the longest business session on record, 9:30 a.m. to 5:30 p.m. with an hour off for lunch.

Along with 12 technical papers was presented a highly successful panel discussion on railroad smoke control. There also was a panel discussion on the new ASME Model Smoke Law.

May 27 was devoted to an all-day inspection trip of the Experimental Installation on Underground Coal Gasification being carried on jointly by the U. S. Bureau of Mines and the Alabama Power Co. at Gorgas, Ala.

After Mr. Kugel's Nominating Committee submitted its report, the following officers were elected: Louis J. Cudbird, chief smoke inspector of Toronto, president; L. C. McCabe, director of the Air Pollution Control Department of Los Angeles, first vice president; Walter Sample, fuel supervisor of the Baltimore and Ohio Railroad, Baltimore, second vice president; Mr. Chambers, secretary-treasurer; Dan A. Sullivan, director of public relations; and Joseph M. Dorrer, Chicago Junction Railroad, Chicago, sergeant-at-arms.

Mr. Sullivan presented his special committee's report on the investigation of the smog disaster at Donora, Pa. A motion was adopted to include future committee reports in the proceedings of the annual meetings.

The Auditing Committee's report showed receipts up to May 23 of $3503.53 with a balance on hand of $4199.48.

One of the highlights of the session was a resolution that the Association sponsor the fourth week in October each year as National Smoke Abatement Week with the slogan, "Pure Air Is Healthful—Let's Keep It Clean."

Opposition Met

The report on the proposed revision of the constitution and by-laws led to a lengthy discussion that was described aptly by one member as "acrimonius." The biggest debate was over the manner of electing officers, and many of the old-timers were opposed to much if any change.

George Ritchie moved successfully, however, to have Article Five of the Constitution amended by adding the words "or by a $^3/_4$ths vote of members voting by letter ballot." He also succeeded in amending Section Seven of the by-laws by adding the words "or by a $^2/_3$rds vote of members voting by letter ballot."

The Special Committee on revision presented three titles for possible adoption as the new name of the Association. They were: American Association for Air Pollution Control, Air Pollution Control Society, Society for Air Pollution Control.

This led to much discussion, with many of the members wanting to preserve all or at least part of the name which had been used for over 40 years. Finally J. H. Carter made the following motion which was adopted: "That the president appoint a committee of 15 composed of the following members: T. C. Wurts, T. M. Jewell, E. D. Benton, F. A. Chambers, H. C. Ballman, W. E. Tidmore, R. E. Nichols, A. A. Raymond, E. R. Kelly, G. V. Williamson, C. F. Hardy, W. E. E. Koepler, L. F. Lang, H. E. Aldrich, and Marc Bluth, the last named to act as secretary; that the committee be empowered to elect its chairman and to review the suggestions for a new constitution and by-laws, which, upon approval of a majority of the officers of the Association, shall be submitted to the membership for approval by letter ballot; further, that if a revised constitution and/or by-laws are approved, the officers of the Association be empowered to proceed forthwith to place the newly adopted provisions into effect."

Soon after the Birmingham meeting, the committee elected Henry Aldrich temporary chairman and went to work on the new constitution and by-laws. Later that year the proposed revision was presented to the members for a letter ballot.

The balloting closed at midnight Jan. 6, 1950, and the tellers met in Chicago four days later and announced the following results of the ballot count:

For adoption of the new by-laws, 140. Against, 83.

For adoption of the new name "Air Pollution Control Association of America," 136.

For retention of the name "Smoke Prevention Association of America," 73.

Inasmuch as the revision did not receive the necessary $^2/_3$rds vote, President Cudbird referred the subject back to the Special Committee and stated that further action would not be taken prior to the annual meeting in Montreal in June of 1950.

Fight Ensues

The 1950 meeting in Montreal, Can., May 22–26, resulted in a showdown battle over the proposed amendments to the constitution and by-laws.

The changes, formulated by the Committee of 15 during the year, had been submitted to the membership by letter for balloting. One of the main points was changing the Association's name to "Air Pollution and Smoke Prevention Association of America."

The amendments went down to defeat, failing to receive the necessary two-thirds vote.

During the annual meeting, the committee revised the proposals and John Hodges moved that they be adopted. He was backed by T. H. Buchanan of the Pennsylvania Railroad, Chicago.

The motion was lost again, however, by a standing vote of 44 in favor and 78 against. Then a vote was taken on the original changes proposed by the committee, with the result of another defeat by a score of 85 in favor and 48 against.

Reconsideration Asked

Harry Ballman moved for a reconsideration and that's when Secretary Chambers stepped in and made his big pitch. He pleaded for its passage, stating that he thought it would be very unfortunate for the Association if it adjourned without adopting the new by-laws.

The result: 105 votes for, 33 against.

Then Mr. Buchanan, seconded by Mr. Kunkel, moved that the vote be made unanimous. The motion was carried.

J. H. Carter, chairman, presented the report of the Committee on Standards for Emission of Solids. This included a table of allowable emissions for various rates of steam generation which brought a dissenting opinion from H. H. Bubar.

After considerable discussion, the report was made a part of the minutes with the proviso that it be submitted to the members and interested parties with the idea that final action be taken at a later date.

Incidentally, these allowances later that year were incorporated into the regulations of the Bureau of Smoke Control, New York City. They are still a part of that City's Department of Air Pollution Control.

H. K. Kugel, chairman of the Nominating Committee, submitted the nominations made up in accordance with the revised by-laws. He explained that inasmuch as this was the first year, it was necessary to make nominations for one, two, and three-year terms. The nominations:

For one-year terms—Charles Gruber, Cincinnati, president; James H. Carter, St. Louis, and Harry Kunkel, Los Angeles.

For two-year terms—John Hodges, Philadelphia, and Fred Classen, Wyandotte, Mich.

For three-year terms—T. C. Wurts, Pittsburgh, and W. E. Tidmore, Atlanta, Ga.

In the general field of industry and

business, these were the nominations:

For one-year terms—G. V. Williamson, St. Louis, and John T. Doyle, Greenwich, Conn.

Two-year terms—E. E. Smauder, Detroit; George R. Hill, Salt Lake City, and William L. Stewart, Los Angeles.

Three-year terms—Dr. Louis C. McCabe, Washington, D. C.; Henry F. Hebley, Pittsburgh; and A. A. Raymond, Buffalo, N. Y.

The nominations, moved and seconded respectively by F. S. Giles, New York, and C. N. Howison, were accepted.

Chairman Harry Ballman gave the Incinerator Committee report, dealing with definitions and a set of objectives for various types of incinerators.

The report of the Committee on Vapors, Fumes, and Noxious Gases, presented by Chairman Harry Kunkel, dealt mostly with dust from various processes and the Los Angeles regulations.

Other reports were made by J. E. Brown, chairman of the Marine Committee; Dan Sullivan, head of the Public Relations Committee, and C. N. Howison, who was handling National Smoke Abatement Week.

Frank Chambers Dies

The 1951 meeting at Roanoke, Va., May 7–10, started off with bad news. Frank A. Chambers, the secretary for 43 years, was dead. He had died March 25, 1951.

Glowing tributes to the work Mr. Chambers had done for the Association were made by Leonard Lang, representing the Industrial Equipment Manufacturers, and Bill Christy, past president, who spoke for the control officers and other members. A resolution of appreciation was unanimously adopted.

President Gruber presented the organization chart adopted by the board. He also reported on a meeting of the Central States Section of the three regional sections which had been organized.

Dr. H. P. Munger and the Battelle Memorial Institute were lauded for the great job they had done without cost to the Association.

Tom Wurts, chairman of the Management Committee, reported arrangements had been made with the Mellon Institute in Pittsburgh for office space and other facilities. Robert T. Griebling was appointed Executive Secretary.

The Finance Committee reported membership stood at 33 company members, 69 sustaining members, and 389 individual members. Dues amounted to $22,790.

Carroll Hardy, chairman of the By-Laws Committee, presented several revisions that resulted in considerable discussion. It was eventually moved that the proposed amendments be referred to the committee for further study with a vote to be taken later by mail ballot.

John L. Hodges, chief of the Division of Air Pollution Control for Philadelphia, was elected president.

At the 1952 meeting in Cleveland, June 9–12, President Hodges and Executive Secretary Griebling reported the design of an emblem for the Association and the publication of *Air Repair*,

a quarterly publication. They also verified the report that Mellon Institute had provided office space and other facilities free of charge.

Membership, according to Chairman Henry Hebley, had risen to 54 companies, 77 sustaining, and 451 individuals.

Chairman Tom Wurts of the Finance Committee reported receipts of $25,867, disbursements of $22,074, and a net worth of $24,574.

Carroll Hardy, chairman of the By-Laws Committee, suggested the name of the Association be changed to Air Purification Society, but the matter was put to a mail ballot. The name chosen, with only three dissenting votes, was Air Pollution Control Association.

James H. Carter, smoke commissioner of St. Louis, was elected president.

At the 1953 meeting in Baltimore, May 26–29, the Finance Committee reported a net worth of $25,169. Charles Gruber reported membership had grown to 91 companies, 80 sustaining, and 510 individuals.

Air Repair Goes Technical

Henry Aldrich, Publications Committee chairman, announced *Air Repair* was to become strictly a technical journal, taking the place of the former proceedings report. They also announced the intention to enlarge *APCA News* and have it printed.

A resolution was adopted in honor of the late W. E. E. Koepler, the Association's "Roving Ambassador of Good Will." A similar resolution was adopted for H. G. Dyktor, of Cleveland, and J. G. Mingle, Indianapolis.

T. C. Wurts, director Allegheny County's smoke control program at Pittsburgh, was elected president.

Highlight of the Baltimore meeting was the entertainment of the entire convention by Koppers Co. An excursion steamer took the members around Baltimore Harbor and then down to Annapolis for a sea food dinner.

The 1954 meeting at Chattanooga, Tenn., showed membership had reached to 125 companies, 81 sustaining, and 613 individuals.

J. H. Carter, chairman of the Awards Committee, discussed the establishment of the Frank A. Chambers Award for meritorious accomplishment in the field.

President Wurts reported that Robert Griebling had resigned and that Harry C. Ballman had been named as the replacement.

Elected president was Col. Gordon P. Larson, director of Air Pollution Control of Los Angeles County.

A recommendation by the Membership Committee to establish a fourth class of membership namely Contributing Members, was discarded. It was recommended that dues of sustaining members be raised to $250. Membership was cited at 159 companies, 88 sustaining, and 776 individuals.

The Finance Committee reported the net worth had grown to $39,256.

The new president was H. K. Kugel, director of Smoke Control and Boiler Inspection for the District of Columbia.

The name of the technical publication was changed to the JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION.

The first Frank A. Chambers Award went to Dr. Moyer D. Thomas. At the same time it was announced that the Richard B. Mellon Award had been established.

The Mid-Atlantic States Section had been organized and its first meeting

was held at Rutgers University. A Bibliographic and Abstracting Service also had been created.

During the 1956 meeting at Buffalo, May 21–24, it was announced that St. Louis had been selected as the site for the 1957 Golden Anniversary meeting.

Membership had grown to 178 companies, 90 sustaining, and 962 individuals. The new president was Benjamin Linsky, then in charge of Air Pollution Control for Detroit but now doing the same job for the Bay Area at San Francisco.

Behind the Scenes

Following the Annual Meeting held in New York in 1948, a number of air pollution control officials located in the Middle West felt the need of meeting more frequently than once a year to discuss their common problems. Un-

doubtedly they were also concerned with the changes they felt were needed in the Smoke Prevention Association of America and the need for expanding it. In October, 1948, Charles Gruber, in charge of Air Pollution Control in Cincinnati, took the lead and wrote a number of Mid-Western air pollution control officials inviting them to attend a meeting in Columbus, Ohio, on October 29, 1948.*

Conference Organized

At the 1947 meeting in Toronto, and also in New York in 1948, informal conferences of smoke inspectors had been held. In the business session of the 1948 New York meeting it was decided to have a committee appointed to organize the Conference of Smoke Inspectors. Charles Gruber was appointed Chairman of this Committee. At the meeting held in Columbus there were eighteen representatives of twelve cities and Allegheny County, Pennsylvania, in attendance. Charles Gruber was unanimously elected Chairman of the meeting and Charles Howison, of the Air Pollution Control League in Cincinnati, was elected Secretary. The Chairman appointed a Steering Committee with the late Herbert Dyktor of Cleveland, Chairman, and Robert Wolf, of Indianapolis, Secretary. Other members were: Tom Wurts, Harry Ballman, Roy Diehl, and W. C. Lehman. The name of this committee was changed to Committee on Research and Development. Later in the session the Committee recommended obtaining a copy of the Constitution and By-Laws of the Smoke Prevention Association of America for study. Chairman Gruber stressed the urgency for preparing a program to be submitted at the annual business meeting of the SPAA at Birmingham in May, 1949. It was decided to hold another meeting of this group in Cincinnati in March, 1949. The group also decided to call themselves Air Pollution Control Officials Conference.

Another meeting of this group was held in Cincinnati, Ohio, on March 11, 1949. There were twelve in attendance. A rather comprehensive report of the Committee on Research and Development was given by the Chairman, H. G. Dyktor. Resolutions drawn up by the Committee were presented to the Conference and universally adopted. These resolutions, quoted in full, are as follows:

"Be it Resolved that the Conference recognizes that the art and science of air pollution control has expanded at a tremendous rate in recent years, and is no longer to be described as 'smoke control' or 'smoke prevention.' Recognizing this expansion and the need for a national organization of technicians working in this field, the Conference recommends this need be met by an expansion of the aims and purposes of the Smoke Prevention Association of America. In order to accomplish this purpose, we recommend that the following changes be made:

"We recommend that the name of the organization be changed from the Smoke Prevention Association of America to a more general name.

"We recommend that the charter of the organization be amended to change the present purpose, which is now stated as—

> 'The abatement of a public nuisance the preservation of health and the conservation of fuel. It fosters propaganda seeking the adoption of various methods, and attempts to educate the owners and operators of fuel burning equipment, in the cause, effect and remedy of the emission of dense smoke,'

to a more general purpose emphasizing air pollution control, and the establishment and dissemination of technical standards. We recommend extensive revision of the Constitution and the formation of a Constitutional Revision Committee to complete the details.

"We specifically recommend the following constitutional changes:

A The establishment of membership grades as follows:
  1 Full members with appropriate qualifications.
  2 Associate members with appropriate qualifications, but having no voting power.
  3 Substaining members.
B We recommend that officers be limited to full members.
C We recommend the establishment of a governing body, such as a Board of Governors or Board of Directors.

"We recommend the establishment of a proper journal as is required by the needs of the members for the exchange of ideas.

"We recommend that the new Constitution be implemented by proper by-laws.

"We recommend the following as reasonable requests be made upon the present officers of the Association:

A That the membership of the Smoke Prevention Association of America receive a roster of membership, and a detailed financial report at the Birmingham Convention;
B That the officers of the Smoke Prevention Association take adequate steps to insure that only qualified members vote during the business session of the Birmingham Convention."

The proceedings of the 1949 SPAA business meeting show that practically all of these matters were brought up and discussed at the all-day business session.

Form Regional Section

The next meeting of the Air Pollution Control Officials Conference was held in Cleveland, September 15 and 16, 1949. There were 24 in attendance. This meeting was mostly of a technical nature. At the brief business session it was decided to hold meetings semi-annually.

Another meeting was held in Toledo, Ohio, March 23 and 24, 1950. There were thirty-nine in attendance including representatives of several communities which had not participated previously. This meeting was also largely technical.

At a meeting held in Columbus, Ohio, September 14 and 15, 1950, there were thirty-three in attendance. A motion was adopted to apply to the APCA for permission to meet as a Regional Section of that organization.

The sixth semi-annual meeting was held in Pittsburgh, February 8 and 9, 1951, with Harry C. Ballman as Chairman. Charles Gruber had been elected President of the APCA. Harry Ballman read a letter from President Gruber stating that the Board of Directors of APCA had voted to accept the application of the group to affiliate as a Regional Section of the parent organization. The name chosen was the East Central Section. Charles Gruber also presented an Organization Chart, which he drew up when elected President of the APCA and which is labeled "Futuramic." This chart is somewhat similar to the Organization Chart later adopted by the APCA.

In Retrospect

Despite a series of ups and downs, the Association grew tremendously during its first 50 years.

Although minutes of the early meetings are sketchy or non-existent, a report of the 1914 meeting shows that the 34 members paid dues of $5 per year.

J. H. Lewis, during his election as an honorary member at the 1926 meeting, recalled that there were only 12 members when he joined the Association in 1910. And they had to chip in to foot the expenses of the meeting.

Politics, as it does with most organ-

---

* After the History was presented at the St. Louis Meeting in June, 1957, Charles Gruber approached me and told me briefly about the several meetings of Control Officials in the Mid-West, starting in 1948. I was not familiar with these and Charles kindly sent me the records of these meetings and his comments which he had carefully preserved. Undoubtedly they should be made a part of the History, particularly on account of their connection with the reorganization.

izations, frequently played a role in Association affairs, especially during the 1930's and 1940's. This was particularly true in the election of officers and sometimes in the selection of locations for the annual meetings. This, unfortunately, created friction at times among the membership.

During the Big Depression of the 1930's there was some question that the Association could keep going. It was the custom to collect annual dues only from those attending the meetings. Unfortunately, many of the smoke inspectors and control officers couldn't get the municipalities to pay their expenses. Several of them paid their own out of loyalty to the Association.

Railroaders Helped

A special credit should go to the railroad men during those trying times. Traveling on passes, they usually could obtain authorization to attend the conventions and many of them brought their wives. At some of the meetings there were more railroad men present than any other group. There is no doubt that they played an important role in keeping the Association on its feet.

Great credit must go to these four founders of the Association: John Fairgrieve, Detroit; R. C. Harris, Toronto; John Krause, Cleveland; and Charles Poethke, Milwaukee.

From other available data, it appears that the following men were active in the early days of the Association: J. W. Burrows, St. Louis; Dan Maloney, Newark; W. A. Pittsford, Chicago; M. A. Rooney, Nashville; and S. H. Viall, Chicago.

The following list is by no means complete, but in it are the names of many members who played important roles during the past quarter-century.

Ernest B. Brundage, Rochester; Frank A. Chambers, Chicago; James H. Carter, St. Louis; L. J. Cudbird, Toronto; Prof. S. B. Ely, Pittsburgh; Frank Gibbons, Detroit; Charles W. Gruber, Cincinnati; John L. Hodges, Cleveland; Charles N. Howison, Cincinnati; J. B. Hurley, Decatur, Ill.; E. R. Kelly, Chicago; W. E. E. Koepler, Bluefield, W. Va.; H. K. Kugel, Washington; Thomas W. Langford, Birmingham; George G. Ritchie, Richmond; W. C. Shove, New Haven; Dan Sullivan, Chicago; Frank Trumbull, Buffalo; Joseph M. Whalen, St. Louis; Martin W. Whelan, Cleveland; and C. G. Wilcox, Baltimore.

Acknowledgments

This history was by no means a one man job. Valuable assistance was received from many of our members as well as several people who were not members. Our Association had no records whatever of the meetings held in 1906 to 1912 inclusive. This meant a lot of digging.

Dan Sullivan was most helpful. He supplied quite a bit of information and then put me in touch with Paul Bird who is probably the oldest living member. Bird supplied us with much valuable data on the early history.

Tom Carey turned some of my letters over to Miss Elizabeth Baughman, Research Librarian, of the Chicago Historical Society. She made a thorough search of old newspaper files in the Historical Society Library. Photostats of articles appearing in the Chicago papers about some of the annual meetings gave us clues to the locations of other annual meetings. Then control officers in Milwaukee, Detroit, Cleveland, Newark, Syracuse, Minneapolis, and Indianapolis searched the files in their public libraries. Ray Wetzel had a double job. After he had searched through June without success, we found from accounts of the Newark Meeting that the date of the next annual meeting was changed to September. We secured photostats of articles about the meetings in papers of all the cities mentioned.

Bob Boelens made a search of the Grand Rapids papers for some account of the 1925 meeting but the only thing he could find was a picture.

Ken Kugel was of invaluable help. He not only sent me his personal files but wrote to a lot of people for information. A complete list of those who had a part in compiling this history follows:

Control Officials

John E. Brown, Milwaukee County
Ernest Brundage, Rochester
Robt. Boelens, Grand Rapids, Mich.
Geo. R. Bean, Minneapolis
Thos. H. Carey, Chicago
L. F. Cudbird, Toronto
J. H. Carter, St. Louis
John L. Hodges, Cleveland
H. K. Kugel, Washington
Benj. Linsky, Detroit
F. J. McArdell, Syracuse
Milton Reizenstein, Baltimore
Wm. B. Schaum, Newark
Raymond E. Wetzel, Indianapolis

Others

Paul P. Bird, former President SPAA, Former Chief Smoke Inspector, Chicago
Miss Elizabeth Baughman, Reference Librarian, Chicago Historical Society
Miss Gertrude Cahalan, Reference Librarian, Newark Public Library
Harry C. Ballman, Former Executive Secretary, Air Pollution Control Association
Henry Aldrich, American Boiler & Affiliated Industries, New York
Thos. A. Marsh, Construction Engineer, Lakewood, Ohio
John F. Barkley, B. of M., Washington
Dan Sullivan, Chicago

Older Members of APCA (In Point of Service as of 1960)

Year Joined	
1907	Paul P. Bird. Oldest member. He was President of International Association for Prevention of Smoke in 1910. He was Chief Smoke Inspector of Chicago 1907–11. He was evidently not a Charter Member but joined shortly after the association was organized. Mr. Bird went into Consulting Engineering in 1911 after resigning his position in Chicago, and dropped out of the organization. He is now retired and living in Cohasset, Mass.
1911	Thomas A. Marsh. At one time with Combustion Engineering, Inc., and for many years National Industrial Engineer of the Iron Fireman Company with headquarters in Cleveland. He is now retired and doing some Consulting Engineering work, living in Lakewood, Ohio.
1920	George G. Ritchie. Coal Traffic Manager—Engineering, Chesapeake and Ohio Railway Company, with headquarters in Richmond, Virginia. Very active in the Association for many years. Served as Officer and on various committees. He is now APCA member of longest standing.
1920	Dan A. Sullivan. Consultant, Commonwealth Edison Co., Chicago, also Secretary-Treasurer, National Military—Industrial Conference. He recently retired from his regular position with Commonwealth Edison but was retained as a Consultant. He held various offices in the Association and also served as Chairman of at least two committees. He was very successful as a Membership Committee Chairman, and also for some time had charge of Public Relations. Dan worked closely with Frank Chambers for many years.
1920	Glenn M. Jewell. Formerly Chief Smoke Inspector, Grand Rapids, Michigan. Retired in 1950 and dropped membership in the Association at that time.
1923	John F. Barkley. Chief Coal Technologist, U. S. Bureau of

(*Continued on page 174*).

Plans For APCA's 53rd Meeting Shaping Up As May Date Nears

The 53rd annual meeting of APCA will be held Sunday through Thursday, May 22–26, at the Netherland-Hilton Hotel in Cincinnati.

This will be a busy and profitable convention for everyone professionally concerned with air pollution. There will be an intensive schedule of technical sessions oriented toward all phases of this problem. In many cases sessions on different subjects will be scheduled concurrently so that each registrant may devote maximum time to his area of special interest. In all, 69 presentations will be made at the 18 technical sessions. *A detailed preliminary schedule is presented in this issue of* APCA JOURNAL.

Of special interest is the Keynote Session on Tuesday following the President's luncheon. Prof. V. A. Riazanov of the Institute of Higher Medical Education, Moscow, USSR, will discuss air pollution problems of his country.

Other special features of the technical program will be plant tours and equipment displays. Plans already completed make it possible to offer four tours of industry and research installations where outstanding work on air pollution control is being done. Equipment displays will be located in the hotel near convention headquarters.

A special events schedule also has been developed. These events include a Sunday evening pre-convention mixer for early arrivals, the President's luncheon and presentation of awards Tuesday noon, and on Wednesday a full evening of fun at the APCA Gay 90's banquet and review. The evening's entertainment, dedicated to recreating Cincinnati's German "Over-the-Rhine" atmosphere, will include a German band, a seven-act review, music for dancing—and no speeches.

There is also a full schedule for registrants' wives. Wives may attend any or all technical sessions. Or, they may spend their time, beginning with a coffee hour each morning, seeing Cincinnati, a picturesque and beautiful city which is at its best in May. A complete schedule of the Ladies' Program also is presented in this issue.

APCA's 53rd annual meeting promises to bring together the leaders in all fields of air pollution work from this country and abroad for an intensive week of work and discussion. The APCA's national and local committees are working to make this a memorable meeting—important for the exchange of technical information and a pleasure for registrants and their wives.

Registration

Full registration information was sent to all APCA Members in mid-March. If you did not receive your registration kit or would like additional kits sent to persons you feel would be interested in the APCA's 53rd Annual Meeting, send your request to:

Air Pollution Control Association, 1960 Meeting
2400 Beekman Street
Cincinnati 14, Ohio

Registration information will be sent AIR MAIL.

LADIES' PROGRAM

Coffee hour at the hotel each morning

Monday—Morning tour of scenic Cincinnati with lunch at the Cincinnati Art Museum

Tuesday—Afternoon tour of historical local churches with tea at beautiful Taft Museum

Wednesday—Trip to the top of Carew Tower to see Greater Cincinnati, and tour of Robert A. Taft Sanitary Engineering Center

Thursday—Morning tour through Procter & Gamble plant—free samples

Tours Highlight Annual Meeting

Tour I

1 PROCTOR AND GAMBLE CO., soap detergent and drug products manufacturing and packaging plant. Process equipment and manufacturing facilities, dust, and odor control.

2 BARRETT DIVISION ALLIED CHEMICAL CORP., asphaltic concrete paving materials drying and mixing plant with baghouse dust control system.

Tour II

1 CINCINNATI MILLING MACHINE CO., Foundry Division, gray iron cupolas with water curtain type dust suppressors; wet type dust controls at core-digging, mold-shaking, and shot-blast equipment and dry type dust controls at grinding units.

2 HILTON DAVIS CHEMICAL CO., Division, catalytic fume combustion unit for effluents from varnish cooking; varied types of dust and odor control devices in chemical manufacturing processes.

Tour III

1 BARRETT DIVISION ALLIED CHEMICAL CO., asphaltic concrete paving materials drying and mixing plant with baghouse dust control system.

2 CINCINNATI GAS & ELECTRIC CO., exceptionally smoke-free incinerator for wire burning and salvage of wire.

3 CARLISLE CHEMICAL WORKS, INC., chemical manu-

(*Continued on next page*)

LADIES' TOUR FEATURE—The Taft Museum in Cincinnati will be one of the many interesting stops included in the Ladies' Program during the Annual Meeting.

VISIT THE 1960 APCA EXPOSITION!

At press-time, there were 20 booth spaces for our 19 exhibiting companies at the 1960 APCA Exposition which will be held at the Annual Meeting.

Extra features of the Exposition will include a complimentary refreshment booth within the exhibit hall for the benefit of visitors and representatives, as well as expensive electric appliance attendance prizes for which visitors may register at each booth.

Exhibitors and their booth numbers are listed below.

428—Catalytic Combustion Corporation, Detroit, Mich.—catalysts and fume combustion systems for air pollution control and heat recovery.

403—Oxy-Catalyst, Inc., Wayne, Pa.—catalytic fume elimination devices and systems for industry, automobiles, buses and trucks.

416—Wheelabrator Corporation, Mishawaka, Ind.—mechanical dust collection devices.

402—Morse Boulger, Inc., New York, N. Y.—latest model incinerators.

426—The John Wood Company, Bernardsville, N. J.—the new concept in gas scrubbers.

424—The Kirk and Blum Manufacturing Company, Cincinnati, Ohio—specialized dust control equipment.

423—Gelman Instrument Company, Chelsea, Mich.—various test instruments for air pollution control work.

433—Airkem, Inc., New York, N. Y.—industrial odor counteractants for atmospheric odor control and for the neutralization of effluents from manufacturing processes.

430—Research Appliance Company, Allison Park, Pa.—automatic air sampling equipment.

431—Joseph Goder Incinerators, Chicago, Ill.—latest model incineration equipment.

406—Heil Process Equipment Corporation, Cleveland, Ohio—fumes, scrubber and ventilation equipment which is corrosion resistant.

404–405—Scientific and Process Instruments, Div. of Beckman Instruments, Inc., Fullerton, Calif.—lab and process gas analysers.

427—The Chemical Construction Corporation, New York, N. Y.—type of exhibit not yet known.

432—Mine Safety Appliance Company, Pittsburgh, Pa.—latest developments in air filtration equipment and instruments for gas detection.

425—Central Scientific Company, Chicago, Ill.—new field air pollution test kit.

414—Mikro-Products, Pulverizing Machinery Div. of Metals Disintegrating Company, Inc., Summit, N.J.—jet action Mikro-Pulsaire collector which is designed for maximum recovery of nuisance, noxious, and high value dust.

415—Coulter Industrial Sales Company, Elmhurst, Ill.—Coulter Counter, an electronic instrument for particle size analysis and concentration.

Booth not selected—**National Dust Collector Corporation,** Chicago, Ill.—working model of "hydrofilter."

407—The Perkin-Elmer Company, Norwalk, Conn.—latest optical instrumentation for use in the air pollution control field.

Tours Featured

(*Continued from page 138*)

facturing. Removal of hydrogen sulfide, before discharge of emissions to atmosphere, by caustic soda gas scrubbing installation. Effluent monitored by recording automatic hydrogen sulfide analyzer.

Tour IV

ROBERT A. TAFT SANITARY ENGINEERING CENTER, Sanitary engineering research center of U. S. Public Health Service. Research in emission control (auto exhaust—incinerator, etc.), chemistry, instrumentation, meteorology, agricultural effects, and operation of national air sampling network.

MAKING THE ROUNDS—Vistors at the 1959 Annual Meeting found much to interest them in the Exhibit Hall in Los Angeles.

Preliminary Program for Air Pollution Co

Monday Morning, May 23

Session A

Community Surveys

Chairman: HAROLD J. PAULUS, PH.D., Associate Professor, School of Public Health, University of Minnesota.

Pollution Levels in Rural Southern Ontario. B. C. Newbury, Department of Chemistry, Ontario Research Foundation.

Variation of Different Pollutants in the Atmosphere of Mexico City. Humberto Bravo A., Laboratory of Industrial Hygiene, Mariano, Mex.

An Air Pollution Study of a Large Border City, El Paso, Texas. Otto Paganini, Texas State Department of Health.

Session B

Industrial Air Pollution Control

Chairman: LEE SCHREIBEIS, JR., Acting Chief, Bureau of Air Pollution Control, County of Allegheny Department of Health.

The Petroleum Industry's Clean Air Program. George A. Lloyd, Esso Standard Oil Company.

Multipurpose Flare Stack for Control of Process Wastes. Joseph F. Mellor, Jr., American Cyanamid Company.

Ninety-nine Point Nine Eight Percent Efficiency Scrubbing for Combustion Aerosols. G. M. Hein and A. R. Orban, Battelle Memorial Institute.

Session R

General Session

Chairman: WALTER A. QUEBEDEAUX, JR., Director, Stream and Air Pollution Control Section, Harris County Health Unit.

Effects of High Volatile Fuels on Incinerator Effluents. Robert L. Stenburg, Robert P. Hangebrauck, Darryl J. vonLehmden, and Andrew H. Rose, Jr., Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center.

Unsolved Problems with Flue-Fed Incinerators. Elmer R. Kaiser, College of Engineering, New York University.

A Method for Analyzing the Trend in Visibility, George C. Holzworth, U. S. Weather Bureau, University of California, Department of Meteorology, and J. A. Maga, Bureau of Air Sanitation, California Department of Public Health.

Monday Afternoon, May 23

Session C

Air Quality Standards

Chairman: E. R. HENDRICKSON, PH.D., Professor, Department of Civil Engineering, College of Engineering, University of Florida.

Standards for Air Quality in California. John A. Maga and John R. Goldsmith, M.D., California Department of Public Health.

Analysis of California Aerometric Data for the Establishment of Bases for Air Quality Standards. Ralph I. Larsen, Ph.D., Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center.

Application of Air Quality Standards to a Community Problem. Bernard Tebbens, Ph.D., School of Public Health, University of California, and Dale H. Hutchison, Stanford Research Institute.

Effects of Vertical Temperature Difference on Soiling Index. Earl H. Markee, Jr., U. S. Weather Bureau Research Station, Robert A. Taft Sanitary Engineering Center.

Session D

General Session

Chairman: S. SMITH GRISWOLD, Air Pollution Control Officer, Air Pollution Control District, County of Los Angeles.

Eye Irritants Formed by Photooxidation of Hydrocarbons and Oxides of Nitrogen. E. A. Schuck, Stanford Research Institute, and Nicholas A. Renzetti, Ph.D., Air Pollution Foundation.

Relation of Eye Irritation in Synthetic Systems to Atmospheric Eye Irritation. Nicholas A. Renzetti, Ph.D., Air Pollution Foundation, and G. J. Doyle, Stanford Research Institute.

The Occurrence, Distribution, and Significance of Photochemical Air Pollution in the United States and Canada. John T. Middleton, Ph.D., Agricultural Experiment Station, University of California, and Arie J. Haagen-Smit, Ph.D., California Institute of Technology.

Sampling Stations and Time Requirements for Urban Air Pollution Surveys. Donald M. Keagy, William W. Stalker, and Richard C. Dickerson, Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center.

Session E

General Session

Chairman: JOHN H. LUDWIG, Sc.D., Assistant Chief, Research, Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center.

A New Gas-Liquid Interphase Reactor for Air Pollution Control. Felix L. Yerzley, Ph.D., John Wood Company.

Achieving Greater Sensitivity in Source Sampling by the S-N Modification to the High Volume Air Sampler. Morton Sterling and Samuel Nimlin, Detroit Bureau of Smoke Inspection and Abatement.

Comprehensive Area Surveys in New York State. William H. Megonnell, U. S. Public Health Service—Region II, and Charles S. Maneri, P.E., Bureau of Environmental Sanitation, New York Department of Health.

Objective Odor Pollution Control Investigations. Norman A. Huey, Louis C. Broering, and Charles W. Gruber, Bureau of Air Pollution Control and Heating Inspection.

Tuesday Morning, May 24

Session F

Automotive Exhaust Research

Chairman: RICHARD W. HURN, Supervising Power Plant Engineer, Petroleum Experiment Station, U. S. Bureau of Mines.

Lead, Carbon Monoxide, and Traffic. Richard S. Brief, P.E., Medical Research Division, Esso Research and Engineering Company.

Automobile Exhaust Particles—Source and Variation. Herbert C. McKee, Ph.D. and William A. McMahon, Southwest Research Institute.

The Role of Engine Blow-by in Air Pollution. Andrew H. Rose, Jr. and Ralph C. Stahman, Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center.

Exhaust Composition in Relation to Fuel Composition. Robert E. Neligan, Paul P. Mader, Ph.D., and Leslie A. Chambers, Ph.D., Air Pollution Control District County of Los Angeles.

Control Association's 53rd Annual Meeting

Session G

Control Officials Conference

Chairman: RAYMOND SMITH, Chief, Air Pollution Control Section, Department of Public Health, Philadelphia, Pa.

STATE VERSUS LOCAL ENFORCEMENT

Part I—Point of View of Industry

Industry Preferred Local Enforcement. George Best, Exec. Sec., Air and Stream Pollution Abatement Committee, Manufacturing Chemists' Assoc.

Legal Aspects of State vs Local Control. Harold W. Kennedy, Los Angeles County Council.

Part II—Point of View of Government Agency

Why Enforcement Agency Prefers Local Enforcement. Charles Couchman, Baltimore Health Department.

The Preference for State Level Enforcement. Richard E. Hatchard, Oregon State Sanitary Authority.

Tuesday Afternoon, May 24

Session H

Keynote Session

Chairman: GERALD V. WILLIAMSON, Vice President, Union Electric Company, St. Louis, Mo.

Keynote Address. John D. Porterfield, M.D., Deputy Surgeon General, U. S. Public Health Service.

Keynote Address. Cornelius Wndmacher, Assoc. Dean, College of Engineering, University of Cincinnati.

Keynote Address. George T. Minasian, Director of Community Relations, Consolidated Edison Co. of New York.

Wednesday Morning, May 25

Session I

Health Effects Research

Chairman: JOHN GOLDSMITH, M.D., Head, Studies of Health Effects of Air Pollution, California Department of Public Health.

Mortality Studies and Air Pollution Indices. Richard Schiffman, Air Pollution Medical Program, U. S. Public Health Service.

Carcinogenic Bioassays on Air Pollutants. Wilhelm C. Hueper, M.D., William W. Payne, Sc.D., National Cancer Institute, Elbert C. Tabor, Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center, Paul M. Kotin, M.D. and Hans L. Falk, Ph.D., University of Southern California.

Air Pollution and Health; General Description of a Study in Nashville, Tenn. Louis D. Zeidberg, M.D., Vanderbilt University, Jean J. Schueneman, Air Pollution Engineering Research, and Paul H. Humphrey, U. S. Weather Bureau Research Station, Robert A. Taft Sanitary Engineering Center.

Session J

Air Quality Monitoring and Sampling Methods

Chairman: WILLIAM R. BRADLEY, Chief Industrial Hygienist, American Cyanamid Company.

Atmospheric Fluoride Monitoring with Special Notes on Methods and Techniques. Charles R. McHenry, Hoyt Charles, William R. Bradley, and Arthur Crago, American Cyanamid Company.

Dispersion and Effects of Air-Borne Fluorides in Central Florida. E. R. Hendrickson, Ph.D., College of Engineering, University of Florida.

A Recommended Method for Soiling Index Surveys by Automatic Filter Paper Sampler. Charles E. Schumann and Charles W. Gruber, Bureau of Air Pollution Control and Heating Inspection.

The Lead Content of the Atmosphere. Jacob Cholak and L. J. Schafer, Kettering Laboratory, Department of Preventive Medicine and Industrial Hygiene, University of Cincinnati.

Session K

Zoning, Planning, and Administration

Chairman: ROBERT PERMAN, Program Management Officer, Air Pollution Engineering Program, U. S. Public Health Service.

Air Pollution Potential Advisory Service for Industrial Zoning Cases. Milton Breivogel and Akira Hasegawa, The Regional Planning Commission, S. Smith Griswold and James R. Taylor, Air Pollution Control District, County of Los Angeles.

Experiences in Industrial Performance Standards for Zoning. Walter C. McCrone and Marvin A. Salzenstein, Walter C. McCrone Associates.

Meeting the Deterrents to Effective Zoning Control of Area Source Air. Hugh R. Pomeroy, Westchester County Department of Planning.

The Development of Motor Vehicle Exhaust Emission Standards in California. John A. Maga and Gerhardt C. Hass, Bureau of Air Sanitation, California Department of Public Health.

Wednesday Afternoon

Plant Tours

Thursday Morning, May 26

Session L

Meteorological Research

Chairman: MAYNARD E. SMITH, Leader, Meteorology Group, Brookhaven National Laboratory.

An Interim Report on Full-Scale Study of Dispersion of Stack Gases. Francis E. Gartrell, Ph.D., Fred W. Thomas, and S. B. Carpenter, Division of Health and Safety, Tennessee Valley Authority.

Atmospheric Dispersion Over Longer Travel Distances. Glenn R. Hilst, Research Department, The Travelers Insurance Co.

Valley Wind Phenomena and Air Pollution Problems. Ben Davidson, Ph.D., Department of Meteorology, New York University.

The Relationship Between Peak and Mean Concentrations. Irving A. Singer, Meteorology Group, Brookhaven National Laboratory.

Session M

Analytical Methods

Chairman: MILTON FELDSTEIN, PH.D., Director of Laboratory Services, Bay Area Air Pollution Control District.

A Preliminary Survey of Hydrocarbon-Derived Oxygenated

Material in Automobile Exhaust Gases. K. J. Hughes and R. W. Huon, Bartlesville Petroleum Research Center, Bureau of Mines.

Application of Gas Chromatographic Methods for Air Pollution Studies. Leslie S. Ettre, Perkin-Elmer Corporation.

Gas Chromatography Analysis of Combustion Effluents. William N. Tuttle and Milton Feldstein, Ph.D., Bay Area Air Pollution Control District.

An Inspection Method for Automobile Hydrocarbon Emission. Robert L. Chapman, Beckman Instruments Company.

Session N

Control Equipment Research

Chairman: ROBERT T. PRING, Technical Director, Dust and Fume Control Division, Wheelabrator Corporation.

Successful Cleaning of Open-Health Exhaust Gas with a High-Energy Venturi Scrubber. C. A. Bishop, W. Wayne Campbell, D. L. Hunter, and M. W. Lightner, United States Steel Corporation.

Research on Control of Emissions from Bessemer Converters. A. R. Orban and J. D. Hummel, Battelle Memorial Institute.

Fabric Filters for High Temperature Gases. Paul W. Spaite, David G. Stephan, Ph.D., and Andrew H. Rose, Jr., Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center.

Rating of Dust Collectors According to Dust Settling Velocities. Wesley C. L. Hemeon, George F. Haines, and S. F. Tuntureri, Hemeon Associates.

Thursday Afternoon, May 26

Session O

Instrument Development

Chairman: ALBERT L. THOMAS, JR., PH.D., Head Instrument Development Section, Southern Research Institute.

Continuous Parts per Billion Recorder for Air Contaminants. J. P. Strange, K. E. Ball, and D. L. Barnes, Mine Safety Appliances Company.

Monitoring Sulphur Dioxide with Lead Peroxide Cylinders. Fred W. Thomas and Charles M. Davidson, Division of Health and Safety, Tennessee Valley Authority.

A Simplified Method for Determining Ozone Levels in Community Air Pollution Surveys. Theodore Vega and Clifton J. Seymour, Riverside County Air Pollution Control District.

An Evaluation of the Aerometric Probe. Paul A. Humphrey, U. S. Weather Bureau Research Station, Robert A. Taft Sanitary Engineering Center.

Session P

Agricultural Research

Chairman: JACK C. SCHWEGMANN, PH.D., Coordinator, Air Control Activities, Kaiser Aluminum and Chemical Corporation.

Status and Redirection of Research on Atmospheric Pollutants Toxic to Field Crops in Southern California. B. L. Richards, Ph.D. and O. C. Taylor, University of California.

Government Sponsored Air Pollution Research Relating to Agriculture. C. Stafford Brandt, Ph.D., U. S. Department of Agriculture Liaison Office, Robert A. Taft Sanitary Engineering Center.

The Biological Scientist in an Air Pollution Control Program. Howard A. James, Bay Area Air Pollution Control District.

Air Pollution from the Grain Industry. Malcolm E. McLouth, Minneapolis Air Pollution Control, and Harold J. Paulus, Ph.D., School of Public Health, University of Minnesota.

Session Q

General Session

Chairman: CLARE M. JEPHCOTT, PH.D., Director, Air Pollution Control Branch, Department of Health, Province of Ontario.

Planning an Environmental Survey of Nuclear Power Plant Site. P. J. Barry, Ph.D., Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada.

Reconnoitering the Air: Procedures for Analyzing Local Air Pollution, Concentrations and Contributions. John H. Smith, Kaiser Steel Corporation, Fontana, California.

Interrelations Between the Levels of Various Particulate Air Pollutants. Elbert C. Tabor and Donald H. Fair, Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Control of Odors from a Continuous Soap Making Process. Jerome E. Molos. Department of Health and Hospitals, St. Louis, Missouri.

Tentative Schedule of APCA Committee and Section Meetings

Parlor	May 22, 1960 Sunday	May 23, 1960 Monday	May 24, 1960 Tuesday	May 25, 1960 Wednesday	May 26, 1960 Thursday
North Hall	a.m. A-2	a.m. A-1	a.m. TI-4	a.m. East Central	
Area		p.m. *	p.m. *	Section (Parlor E)	
"		a.m. A-3	a.m. TI-7	a.m. New England	
		p.m. *	p.m. *	Section	
"		a.m. S-1 & S-1.1	a.m. TI-8		
		p.m. *	p.m. *		
"		a.m. S-7	a.m. TI-10	a.m. Mid-Atlantic	
		p.m. *	p.m. *	Section	
"		a.m. TA-2	a.m. TA-9	a.m. South West	
		p.m. TA-6		Section	
"		a.m. TA-4	a.m. TA-8		
		p.m. TA-7			
"		a.m. S-3 & S-6	a.m. TI-6		
	p.m. S-2	p.m. S-4			
"		a.m. TA-3	a.m. TI-2	a.m. A-5.2 (Parlor F)	
	p.m. A-5.3	p.m.			
"		a.m. TA-5	a.m. TI-3		
	p.m. A-5	p.m.			
"		a.m. TI-1	a.m. TI-5		
	p.m. S-5	p.m.			
E-F	2:00 p.m. Board Meeting	2:00 p.m. Board Meeting	a.m. TR-2 (North Hall)	a.m. Technical Council (Parlor H)	
Hall of Mirrors			Business Meeting 4 p.m. Evening, Local and State Control Officials Forum		

* Rooms not available for p.m. meetings.
All morning meetings are scheduled to begin at 9:00 a.m.
All afternoon meetings are scheduled to begin at 2:00 p.m.

The SMOGLESS Automobile*

by **FRED L. HARTLEY**, Vice President, Research, **C. C. MOORE**, Consultant, and **J. B. GREGORY**, Section Leader, Union Research Center, Union Oil Co. of Calif., Brea, Calif.

As a result of large capital expenditures and increased production costs, which in the long run must be paid for by the consumer in increased product prices, essentially all industry in Los Angeles County is in compliance with the regulations of the Air Pollution Control District. Pollution by industry is approaching the practical minimum consistent with man's desire to possess and enjoy the benefits of a modern society. Specifically, for example, the oil industry has learned how to design and operate what can be called the "smogless refinery." Nevertheless, smog, i.e., lack of visibility and eye irritation, continues unabated throughout the community. Its intensity varies with atmospheric conditions and, in particular, varies with wind direction and velocity.

In hindsight, we now know that all concerned failed to recognize the significance of the remaining large source of hydrocarbon air pollutants, namely, the automobile. It also follows that many of the steps taken to eliminate air pollutants from other sources are irrelevant and place an unnecessary burden on the community.

If today's regulations governing industrial emissions were applied to the automobile, one would not be permitted to operate his vehicle. This is because today's automobiles have, as a result of their design and operating characteristics, five openings, or holes, which permit hydrocarbons and carbon monoxide to excape to the atmosphere: The five sources of air pollution from today's cars are:

1. External Carburetor Vents.
2. Internal Carburetor Vents.
3. Gasoline Tank Vent.
4. Crankcase Vents.
5. Exhaust Pipe.

To produce a smogless automobile it is therefore necessary to either plug up the holes or modify the design, including hydrocarbon and carbon monoxide-eliminating equipment. To date major research and development effort has been placed on the solution of the exhaust gas pollution problem. Important as this is, we are of the opinion that the first three sources of air pollution also require remedial action. In some quarters it is stated that this can be accomplished by changing gasoline characteristics. Our studies confirm that this is not technically feasible. Furthermore, steps in this direction can only result in increased gasoline costs to the motoring public and, unfortunately, only partial reduction in air pollutants, when what is required and demanded by the public is essentially complete elimination. It is the purpose of the paper to outline and propose an adequate solution to the problem.

It is well recognized that gasoline evaporates from the fuel systems of automobiles and finds its way into the atmosphere. This evaporation occurs chiefly from the carburetor float bowl and the fuel tank. Recent studies we have made show that these losses are significant and can amount to 20–30% of the total hydrocarbons emitted from cars in the Los Angeles Basin.

Our purpose is to show how current fuel systems may be changed to effectively reduce, if not virtually eliminate, these losses. These changes are quite simple and straightforward, and if made during the manufacture of the car, should be relatively inexpensive. What we have done essentially is to "plug up the holes" from which evaporation losses occur. In Fig. 1 are shown the major points in the fuel system at which gasoline vapors enter the atmosphere. It will be noted that emissions occur from (1) the external vent in the float bowl, (2) internal carburetor vents (more properly called balancing tubes), and (3) from the fuel tank vent. Obviously, the fuel in the float bowl is constantly exposed to heat from its surroundings, and gasoline evaporates under these conditions. When the car is running, any fuel vapors which escape through the internal vents will be drawn down into the engine and burned. Vapors escaping through the external vents will contaminate the atmosphere.

For some time it has been the general belief that the external vent is necessary for operating at idle. The automotive people claim that, otherwise, excess fuel would cause an over-rich mixture and rough idle operation. Actually, many cars today have a mechanism which opens the external vent only when the throttle is closing, e.g., idling or decelerating. The fear of an over-rich mixture under these conditions

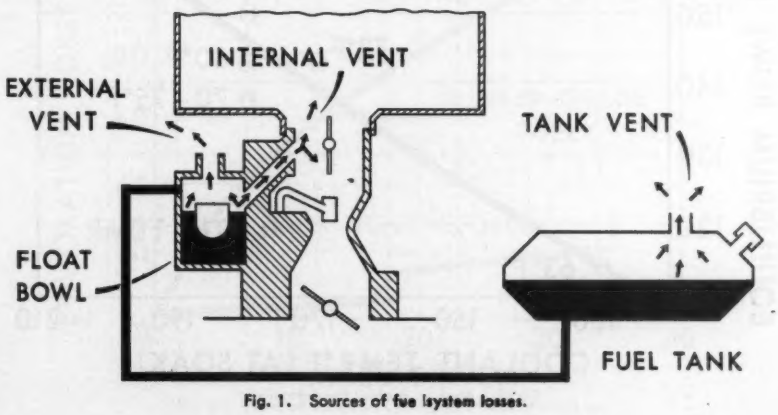


Fig. 1. Sources of fue lsystem losses.

* Presented at the 52nd Annual Meeting of APCA, Hotel Statler, June 21–26, 1959, Los Angeles, Calif.

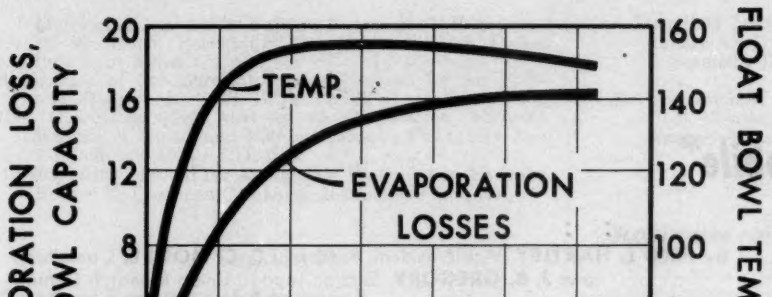


Fig. 2. Hot soak temperatures and losses.

is warranted because the flow of fuel through the float bowl at idle is slower than at any other time when the engine is running. Because the fuel is hotter under these conditions, more fuel will be lost then than at any other time. Investigators, besides ourselves, have found that carburetor running losses are also higher proportionately during idle and deceleration. Our studies have shown that approximately five percent of the total fuel consumed during idle operation can be lost through the external vent.

We ask ourselves whether the external vent is necessary on the modern car. To find out, we intentionally plugged the external vents of a number of automobiles. We have operated them at high altitude and low altitude, have employed winter and summer gasolines, and have run these automobiles under mild and hot weather conditions. There are six of these automobiles of various makes operating in the Los Angeles area now, including the one I drive and four driven by personnel of the Air Pollution Control District. To date we have received no complaints from any of the drivers that plugging the external vent has interfered with normal car operation. There can be only one conclusion: the carburetor vent is like your appendix—you don't need it!

Carburetor evaporation losses also occur during the so-called "hot soak" period of an engine. This hot soak period begins immediately after the engine is turned off. Heat stored by the engine while running is transmitted to the carburetor bowl, which at this point contains from 80–200 ml of gasoline, depending on carburetor design. As the trapped gasoline is heated, evaporation occurs through carburetor vents. During hot soak, the evaporated fuel ultimately reaches the atmosphere, whether its escape path is through internal vents and out the air intake or external vents. Figure 2 shows an example of what happens to the temperature of the fuel in the carburetor bowl during the hot soak period, and also the losses which occur. We have found that this hot soak temperature is primarily a function of engine coolant temperature, rather than atmospheric temperature, as shown in Fig. 3. This means that hot soak losses occur day or night, hot weather or cold, and are therefore greater than have been previously assumed. We believe that evaporation losses during the hot soak period amount to about 40% of the total fuel system losses from cars in the Los Angeles area.

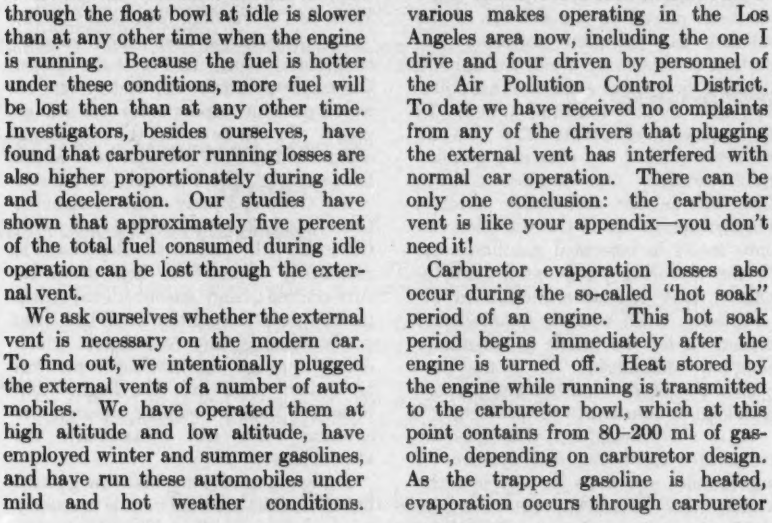


Fig. 3. Bowl vs. coolant temperatures.

In studying the problem, we concluded that the best way to eliminate hot soak losses is to get rid of the fuel from the carburetor bowl during this period. To do this, on several cars we have installed a drain-back system which empties the contents of the carburetor bowl into the fuel tank immediately when the engine is turned off. This system is fitted with a vacuum-operated valve which is closed while the engine is running so that warm gasoline from the carburetor bowl is not continuously circulated to the tank. The drain time of the carburetor bowl is approximately one minute. During this drain time some fuel does evaporate but our experiments show that hot soak losses are reduced by 95%.

With an empty carburetor bowl, the problem of starting the engine quickly with the conventional mechanical fuel pump is immediately apparent. To solve this problem we have installed an electric fuel pump on our experimental cars and have found it most satisfactory. Fuel is immediately pumped into the float bowl when the ignition is turned on. Incidentally, many modern European automobiles come equipped with electric pumps.

Evaporation losses occurring from the fuel tank were examined next. First of all, our tests showed that the fuel in the modern automobile fuel tank becomes hotter than the surrounding air by 10–30°F or more. In cars of about 1939 and earlier, the hot air coming from the engine compartment was vented through louvers in the hood, and a special attempt was made not to have any of this hot air flow under the body of the car. In today's cars all of the hot air is directed down under the car and much of it flows back against the fuel tank. In addition, the exhaust pipes from today's hot-running engines are very often located parallel to and no more than an inch from the fuel tank. Today's fuel tanks are actually made

quite flat, with the result that the surface area of the fuel from which evaporation can occur is virtually at a maximum. Thus, the automotive manufacturers have inadvertently provided an excellent means of evaporating the fuel in the tank.

To correct this, the first thing we did was to insulate the tank. This was done with two thicknesses of asbestos paper, a sheet of aluminum foil, and a final layer of asbestos cloth. The thickness of the insulation is a little more than one-half inch. These were the materials we had at hand and undoubtedly a better insulation can be worked out. Even with this hastily designed insulation, during a short trip on a moderately warm day the rise in temperature of the tank was reduced by 13°F. Figure 4 shows how tank evaporation losses during this trip were reduced as a result of tank insulation. On the average, losses from an uninsulated tank are reduced by about 70%. Furthermore, when the tank is insulated it takes quite a while longer for the fuel in the tank to heat up above the atmospheric temperature. We call attention to this because in our normal city driving the length of trips is quite short and it is under these conditions that the insulation will do the most good.

The remaining step taken was to plug the fuel tank vent that normally serves to keep the tank at atmospheric pressure. This was done by installing a vacuum-actuated valve which closes the fuel tank vent during engine operation. We, as others, find that the vast majority of tank losses occur when a car is being driven. Pressurizing an uninsulated tank is even more effective than tank insulation in reducing evaporation losses, as shown by Fig. 5. By combining both insulation and fuel tank vent closure, we estimate a 90% reduction in fuel tank losses.

Today's fuel tanks are not built to stand a great deal of pressure, and we have found that when five or more pounds is exerted on the interior of a tank it begins to bulge. Also, as fuel is used, a partial vacuum can be created in the tank. When this pressure drops too far below atmospheric it is impossible to draw fuel from the tank and, in addition, the tank begins to collapse. Therefore, we have provided a fuel tank cap which acts both as a pop-off valve in the event pressure exceeds two pounds within the tank and also as a vacuum breaker which allows air to go into the tank as it is required. This last piece of equipment is by no means unusual. The ones we used are Chevrolet Corvette caps.

Pressurizing the tank complicated somewhat our use of the carburetor float bowl drain-back system. If there is pressure in the tank when the bowl is trying to drain, it is conceivable that fuel from the tank could be pushed backward into the float bowl. At least, any tank pressure can prevent drainage of the carburetor bowl. Therefore, we had to provide a means whereby, upon shutting off the engine, the pressure in the tank would be released prior to draining the carburetor float bowl. We have accomplished this by placing in series with the drain-back valve a vacuum reservoir which acts as a delay mechanism in opening the valve. When the engine is shut off, the tank vent valve opens immediately, but the opening of the float bowl drain valve is delayed until the vacuum in the reservoir is relieved. Experimentally, we have set this delay time to be about 15 sec.

One other problem we have encountered is that the pressure in the tank is added to the total output pressure of the particular fuel pump we used. It is possible that the fuel pump could overload the float bowl due to this excess pressure. To control this we used a fuel pressure regulator set for a specified safe value. Obviously this pressure regulating valve could be made an integral part of the electric fuel pump. Figure 6 shows a diagram of our entire system to control evaporation loss from automobiles.

We wish to emphasize again that this system is built up of simple parts which can be incorporated into the fuel system of the modern car. We have satisfied ourselves that 95% of carburetor losses and 90% of tank losses have been eliminated by these changes. We feel that if all cars could be equipped with such a fuel system a significant proportion of the total hydrocarbons now being emitted by automobiles could be eliminated. In the Los Angeles Basin we estimate these losses, on a daily average, at 250–310 tons or 100,000–124,000 gal. Furthermore,

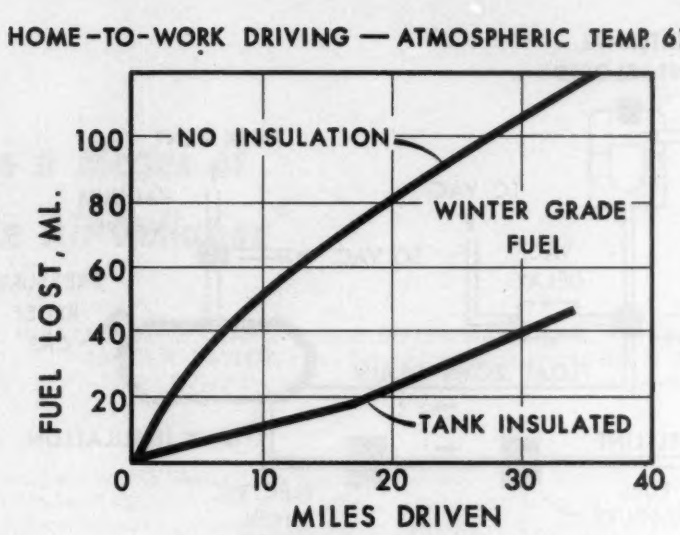


Fig. 4. Effect of tank insulation on evaporation losses.

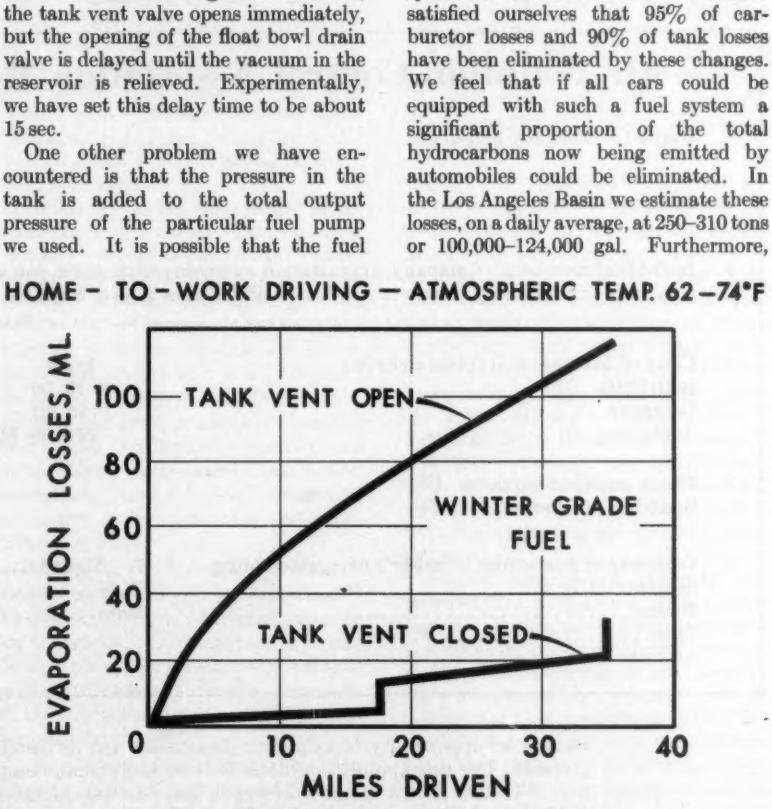


Fig 5. Effect of tank vent closure on evaporation losses.

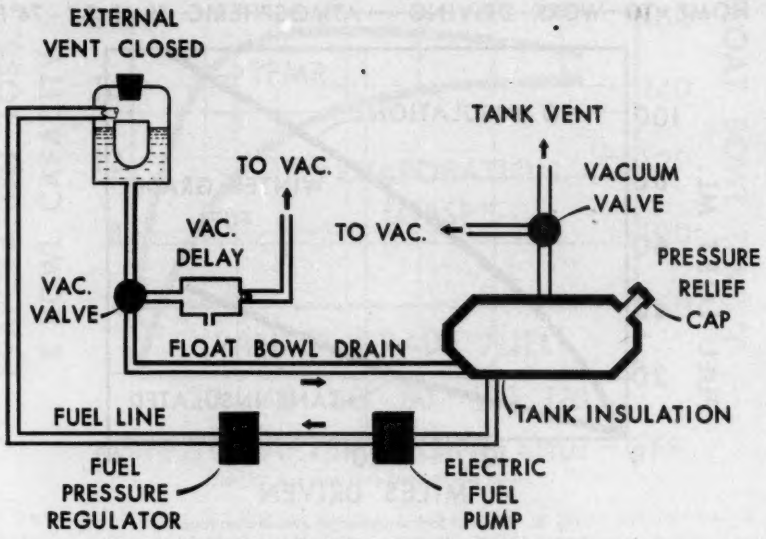


Fig. 6. Controls for fuel system evaporation losses.

this reduction in atmospheric pollution will provide a desirable dividend to the motorist by increasing his gasoline mileage by 1–3%, which in time will pay back the equipment cost.

So far in this paper we have provided what we believe are reasonable and practical solutions to controlling air pollution by capping three of the five holes in an automobile. There are two holes to go. We believe that the crankcase vents can be taken care of by the equipment required to convert the hydrocarbons, carbon monoxide and possibly the oxides of nitrogen in the exhaust gases. Thus, if someone can come up with a practical and proved afterburner, the automobile industry will be in a position to produce a smogless automobile. From our limited work and that of others in the afterburner field we believe sufficient basic research has been done. There is a tough development job ahead to apply the proposed systems to the automobile. Fortunately, the automotive industry is used to making large expenditures for changes which are obsolete in as little time as one year. We believe the buying public, who ultimately pays for these transient changes, is even more than willing to forget about styling revolutions in exchange for a smogless automobile.

As a start, we propose that the 1960 automobiles, and at least those delivered in California, be equipped with the smogless fuel system described herein or its equivalent, or hopefully even a better one. Further,we believe an all-out maximum effort should be made by members of the automotive industry to solve the exhaust gas problem. We are happy to note that there are some signs that this may be the case. May it be true because what is good for the American people could be good for the automobile industry and vice versa. For our part, we are willing to make arrangements under which our developments can be made available to all parties striving to produce the Smogless Automobile.

Air Pollution Control Association Membership Blank

1. Name (or company name).....

2. Mailing address.....

3. Individual members: Company, organization, or agency with whom you are affiliated.....
Company or Sustaining members: Industry affiliation or type of business (steel, petroleum, equipment, etc.).....
.....

4. Class of Membership (please check)

	Dues
Individual ☐	$ 10.00
Company ☐	50.00
Sustaining ☐	250.00 Minimum

5. Check enclosed herewith ☐
Send bill for dues ☐

6. Company or sustaining member's delegated voting representative is:
Name.....
Title.....
Address.....

7. Signed.....
Title.....
Date.....

Here is an opportunity to help your Association get its membership campaign off the ground. Use this application blank for new individual, company or sustaining members. If each APCA member brings in just one new member, we'll be well over the 4000 mark.

INDUSTRIAL ZONING *as a Means of Controlling Area Source Air Pollution**

WILLIAM D. HOLLAND, Senior Research Assistant, **AKIRA HASEGAWA,** Regional Planner, **JAMES R. TAYLOR,** Head Research Assistant, and **ERWIN K. KAUPER,** Senior Meteorologist, Los Angeles County Air Pollution Control District

With all population forecasts indicating continued rapid increases in the Los Angeles Basin to 10–12 million people, it is apparent that the area will take on an increasingly crowded industrialized character. In this situation the possibility exists, as in every other large urban area, that the available supply of air will be insufficient to carry off the pollution emanating from the complex of sources, even when these sources are all controlled to the limits of engineering knowledge. It is obvious that in time a pollution level will be reached, due to the continued increase in industrial development, where the air pollution problem will be re-established. This cumulative effect of the residual emission from many controlled sources in an area has been termed "Area Source."

Industrial zoning has been recognized as a possible means of guiding the development of the Los Angeles Basin, taking full advantage of the limited dispersive ability of the local atmosphere, so that maximum growth can be achieved.

Many California authorities have suggested that the feasibility of controlling the number and type of sources by zoning should be investigated. One of the earlier proponents for industrial zoning was the expert committee on air pollution to the Governor of the State of California, which recommended in the "Beckman Report"[1] in 1953 that "zoning of industry is a matter of greatest urgency from the standpoint of air pollution." Time has not changed the Chairman's—Dr. Beckman—thinking on this approach as indicated in his recent advice to the Southern California Air Pollution Coordinating Council that the industrial zoning principle be also applied on an inter-county basis.[2]

Added impetus to the zoning program was given in 1955, when the Los Angeles Chamber of Commerce, one of the most active advocates for industrial development, issued an unprecedented policy statement.[3] Their proposal recommended that industries without adequate smog control devices be prohibited within this area provided no severe economic effects would result to linked non-smog industries.

That legal obstacles would not interfere was the opinion of the Los Angeles County Counsel provided the air pollution zoning regulation was based on rational grounds.[4] Depending on the situation, air pollution zoning could be exercised to prohibit new industries, limit expansion of existing industries, liquidate non-conforming industries after amortizing their existing investment, or eliminate harmful industries immediately. The sufficiency of supporting data and expert opinion would be the main problem anticipated as far as legal sanction for the zoning program is concerned.

Zoning is one of the police power regulations of local government based on considerations of the public's health, welfare, convenience, comfort, and more recently, amenity and aesthetics. It differs from other uniform police power regulations, such as building and safety, health, fire, etc., in that it can "district" or create varying standards based on futurity and location within the jurisdiction. The traditional classifications have been agricultural, residential, commercial, and industrial zones with sub-zones under each and sometimes hybrids of zones.

Zoning for the reduction of air pollution emissions would be substantiated by objective criteria of dilution capacity for a district. Dilution capacity may be thought of as a measure of the ability of the atmosphere to absorb pollutants to the extent that no discernible air pollution problem exists.

The dilution capacity may vary from place to place in the Basin and depends on wind flow, turbulence, and vertical mixing. The concept of industrial zoning, as a device to control emissions, depends on an ability to describe this dilution capacity. It is ultimately dependent on the refinement possible in the measurement of the governing meteorological variables.

Metropolitan Industrial Zoning Plan

The Los Angeles County Air Pollution Control District (APCD) has undertaken exploratory research contemplating the institution of a Metropolitan Industrial Zoning (MIZ) Plan. Such a program contemplates:

1. The enactment of rules creating a MIZ Plan by the Air Pollution Control Board. (Fig. 1.)
2. The enacted MIZ Plan would be binding on the local jurisdictions—63 incorporated cities and the unincorporated areas within the County.

Since air pollution problems are metropolitan-wide in their effects, industrial zoning for air pollution should be initially considered and handled as a metropolitan problem. The MIZ Plan would limit the air pollution control agency to the enactment of zoning regulations which would permit, limit, or prohibit industrial growth affecting broad areas. This, then would allow the communities and cities to locate industrial zones, based on the non-air pollution factors, in the specific sites they deem best suited for their jurisdiction provided they do not conflict with the overriding air pollution regulations.

Several decades of planning experience has shown that despite conceptual excellence, skillful persuasion and pleasing public relations, effective metropolitan planning is not possible without mandatory powers.[5] It is anticipated that a workable MIZ Plan would not be effective on a voluntary basis but would require mandatory compliance by the constituent local governmental agencies.

---

* Presented at the 52nd Annual Meeting of APCA, June 21–26, Statler Hotel, Los Angeles, Calif.

Air Pollution Control District	Local Government Agencies
Industrial zoning based on air pollution control factors and metropolitan viewpoint.	Industrial zoning based on non-air pollution control factors and local desires.
Criteria to be the variations in the natural dilution capacities of large areas for the residual contaminants after source control.	Criteria to be locally determined, for factors such as: noise, glare, vibration, fire hazards, water pollution, traffic, and air pollution factors.
Preparation and administration of metropolitan industrial zoning plan which is binding on local governments within the metropolitan area.	Preparation and administration of detailed local industrial zoning plan incorporating the metropolitan zoning requirements.
In L. A. County the Air Pollution Control Board would enact rules creating the new metropolitan industrial zoning plan.	In L. A. County the over 60 cities and the County (for unincorporated area) would enact the traditional local industrial zoning plans.

Fig. 1. Relationship of metropolitan and local industrial zoning plans, Los Angles County, California

Degree of Plan Substantiation

In order to legally effectuate the MIZ Plan, substantiation of the zoning plan to some degree is necessary. Three degrees of substantiation are possible as follows:

1. Incomplete or no substantiation, which would immediately lessen public clamor and cost of the project but would increase the possibility of legal setbacks and of unfairness to the industries affected, or

2. Complete substantiation, which would lessen objections from industry and the courts but would increase public impatience and cost of the project, or

3. Zone as you go. That is, try a compromise of adopting a zoning plan upon completion of preliminary studies and provide for a continuing study to periodically refine the original plan as needed.

An attempt to adopt an inadequately substantiated or piece-meal air pollution zoning plan as an expediency would result in the zoning project becoming a political football. The selection of this approach would likely be subject to legal setbacks because some industries might be treated capriciously or arbitrarily.

On the other hand, the complete justification of a zoning plan would be both costly and prolonged. Beyond a certain point, the law of diminishing returns would apply. A complete investigation, even if it could be accomplished, would probably require so much effort and time that it might be mainly of historical or theoretical interest.

The determination of the degree of substantiation would be based upon whether or not time is of the essence and whether the citizens are willing to pay the costs for a crash program. In lieu of complete substantiation, the zoning plan would lean heavily on the reasoned judgment of a technical staff and intensive liaison activity with the numerous local jurisdictions. We recommend a compromise by adopting a zoning plan upon completion of the research outlined in the sections following.

General Approach and Assumptions

The assumption is made that the natural dilution capacity cannot be readily changed. Of prime interest then is the collection and analysis of meteorological data for a sufficient period of time to learn the range of dilution capacity for each area. It would be relatively constant as compared to the growth problem of the sources and receptors.

A further assumption is made that the sources and receptors are constantly growing. The sources are self explanatory. The receptors are the urban population. The sources and receptors are constantly increasing variables.

The general approach to the problem would be to solve the simple equation,

$$\text{Amount} = \text{Volume} \times \text{Concentration}$$

where:

Amount is the weight of the contaminant that can be tolerated in the area, expressed in pounds or tons for an interval of time.

Volume is the natural dilution capacity, expressed in cubic feet or cubic miles for the same interval of time and the same area, and

Concentration is the community air standard or maximum allowable atmospheric concentration, expressed in pounds per cubic feet or tons per cubic mile for the same interval of time.

Mainly for convenience and due to the nature of the data, the smallest unit of area has been chosen as one square mile and the shortest time interval as one hour. Thus, the above relationship can be computed for each square mile and the allowable pollution load determined. As a positive check, actual concentration levels can be measured periodically or preferably on a continuous basis through an air sampling network.

If an acceptable community air standard can be established, the furthest downwind receptor area will be assigned this value. Then, the effect of the upwind areas' contributions can be calculated through the use of wind trajectory study and the source emission survey. The limitations imposed on the upwind areas would be controlled by zoning regulations.

Needed Research

It is axiomatic that there is no substitute for exact knowledge. Research is needed on the following phases of the industrial zoning program: (1) a pattern of natural dilution capacity—meteorological research involving wind movement, stagnation areas, and inversion heights, (2) a determination of community air standards, (3) the size and distribution of existing and future contaminant sources, (4) a classification of industry based on air pollution potentials, and (5) the establishment of adequate air monitoring facilities for measuring concentration levels.

Meteorological Activities

The meteorological portion of the zoning program is the most important of all the phases, since the entire zoning justification is dependent upon it. The scope of this portion is so broad that it could be the subject of a separate paper in itself. Therefore, this discussion will be limited to the highlights only. Briefly, the meteorological research is directed to providing the atmospheric parameters that will be combined with information regarding source emissions to give a measure of the relative pollution potential of various sections of the Los Angeles Basin.

The first step of this study was the establishment of a system of surface wind observing stations. Activated in 1952, this system has grown to its present density of 74 stations, 34 of which are owned by the APCD. The other stations are operated by various industrial concerns or are regular meteorological stations of the armed forces and the Weather Bureau.

Information procured from the wind reports is reduced to the form of hourly maps that indicate the existing air flow patterns over the Basin. These air flow maps are used to follow the course a particular parcel of pollution would take upon its release. The parcel must move in the direction of, and with the speed of, the wind indicated in the area where the parcel is found.

Succeeding hourly maps permit the calculation of a new position for the moving air parcel. The final result, derived through the connection in time-series of the position points, is a

representation of the actual path or trajectory of the air parcel.

While the APCD Meteorology Unit was established to work on the zoning project, non-zoning functions were added to its work load as the capabilities of its specialized services were recognized. For example, the tracing of air parcels by means of trajectories was a key ingredient in the determination that automotive traffic was the main source of air pollution for the central Los Angeles area. The trajectories of polluted air indicated that no source of hydrocarbon emission other than automotive traffic could explain the measured pollution.[6] The air just did not travel over refining sections, for instance, but did travel over high-density traffic areas.

Individual trajectories covering specific periods in past years have been used to trace specific odor complaints, and to localize source areas of air that was discovered to have high pollution values as it passed over air sampling sites.

The first research aimed directly at the zoning problem, involving the use of data from this wind observing network, was that devoted to answering these questions: Does a trajectory calculated from the surface wind station network fit with reality? Can pollution be traced by use of wind observation reports? Affirmative answers were provided through the use of fluorescent tracer tests[7] and other tracers such as mercaptans when accidentally released.

In the latter cases, the locations of public complaints were plotted on maps, and trajectories were constructed backward in time. Verification of the accuracy of the trajectories was made when the source of the accidental release was established to be in the area indicated by a crossing of trajectories from two different groups of complainants.

The next step in the problem was the conversion of the manual trajectory technique to electronic data processing methods in order to attain the necessary volume of trajectory data in a reasonable amount of time. A program was developed for the IBM 650 computer that would do this task.

In essence, Los Angeles County was divided up into a grid system, so that all geographical locations could be identified by x- and y-co-ordinates. This is known as the APCD Grid System. Each square mile of the grid was coupled with certain close-by wind stations, the data from which would be used to move any trajectory point located in that square. The selection of such stations was made on the basis of meteorological experience previously gained and involved the local instrumental and geographical situation that prevailed.

Through the use of the computer, wind trajectories are being plotted for use in this study. However, trajectories alone will provide only a qualitative picture of pollution distribution from a given area. In order to calculate the quantitative dispersive ability of the air, additional information is needed. This information consists of two parts:

a. Horizontal dispersion—The result of the gustiness or turbulence of the air as represented by the character of the wind. This information may be estimated directly from the wind recorder traces or by use of an estimated dispersion effect derived from various types of field experiments that reveal the actual lateral dispersion occurring under given wind conditions.

b. Vertical dispersion—The pollution may mix in the space between the ground and an upper restraining level, the base of the temperature inversion. The height of this mixed layer is directly related to the air's ability to disperse pollutants. The higher the inversion, the larger the volume of air available to decrease the concentration of polution per unit volume.

Community Air Standards

The determination of the maximum allowable concentration for a community is beyond the scope of this paper. This lacuna has to be filled before the zoning project can be fully completed.

Area Source Emission Survey

The complete spectrum of source emission needs to be estimated—not just the industrial—to determine the relative contributions. Experience gained from a pilot study of a square mile in the Gardena area indicated that a land use survey with slight modifications could be the foundation for a source emission survey. This grid square was selected as representative of the County because of its multiplicity of uses and the fact that portions of three jurisdictional units were located there—the cities of Gardena and Los Angeles and the County of Los Angeles.

The location of the various uses, buildings, dwelling units, vacant land, etc., was determined in the field and designated on a base map field sheet. The information from the field sheet was transferred to another base map designated as the Land Use map and is shown in Fig. 2. An overlay tracing was prepared showing the streets, industrially zoned areas, and the air pollution sources as shown in Fig. 3. The emissions from these sources were calculated and are shown in Table I.

Another Land Use map (Fig. 4) for this same area, prepared from Regional Planning Commission (RPC) data, showed the land use as it existed in 1936. Since the only industrial zoning existing at that time was a small area in the M-1 zone classification bounded by 168th St., Carlyle St., Vermont Ave., and Berendo Ave. in the City of Gardena; and the only major sources of air pollution were service stations, no Sources and Zoning map for 1936 was prepared.

A common planning practice is to forecast future industrial areas by analyzing vacant industrially zoned areas. As can be seen by observing the land use changes in 22 years, the vacant industrial land of 1936 was not necessarily the area where industrial expansion took place. This indicates that a complete land use survey will be necessary to estimate industrial expansion and evaluate future air pollution emissions.

Side benefits may result from this survey since a complete physical inventory of every industrial use will be accomplished. Such benefits may be the discovery of industrial uses which are operating without permits from the control agency and will insure that all industrial air pollution sources have been detected.

Using the method developed by the pilot study, work was commenced on a source emission survey for the County. The San Fernando Valley was selected as a starting point, since it is not completely developed. Our experience for the 31 square miles that have been completed indicates that an average work-load unit of 25 man-days per square mile would be required to conduct a source emission survey for a

Table I—Emissions from the Air Pollution Sources in the Pilot Land-Use Survey

Contaminant	Pounds per day
Total Hydrocarbons and Other Organic Gases	209
Industrial Emissions (1–30)	(124)
Service Station Emissions (A–P)	(85)
Total Aerosols	82
Wood Dust	(6)
Metal Fumes	(42)
Other Dusts	(34)
Sulfur Dioxide	5
Oxides of Nitrogen (calculated as NO_2)	50
Carbon Monoxide	10

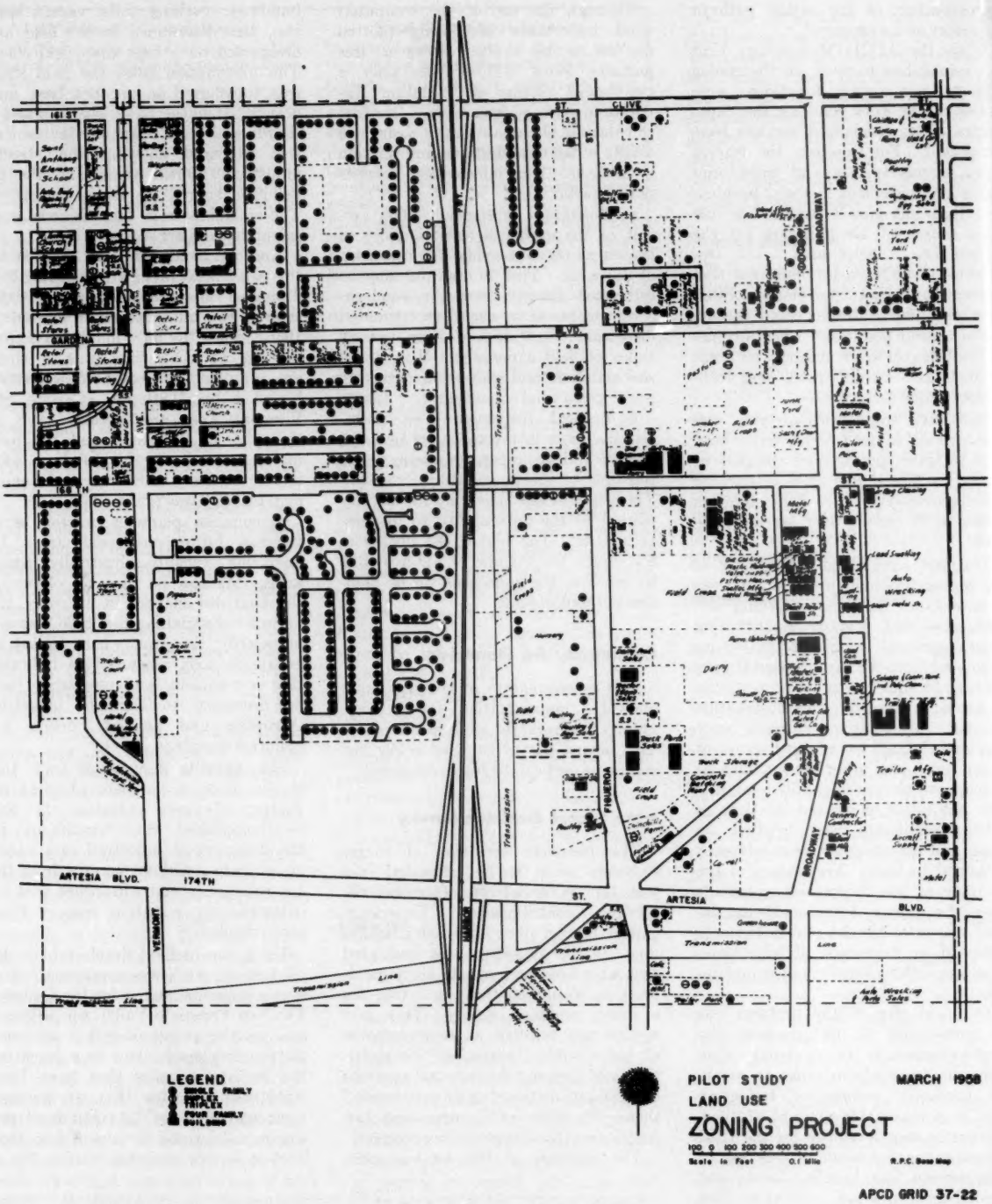


Fig. 2. 1958 Land Use APCD Grid 37-22

similar rapidly urbanizing fringe area of a large central city.

Although the existing source emission survey is easily obtainable with application of increased personnel, the forecasting of future emissions is a most difficult problem. However, the possibility exists for projecting the future growth of industry itself by means of comparison with existing and future population density.

Population density, the ratio of persons to land area, serves as a general measure of population concentration and urban land use. Metropolitan population density is usually expressed in units of persons per square mile or per acre. While unique population density values are useful for city to city comparison, in order to study the Los Angeles Basin itself the variation

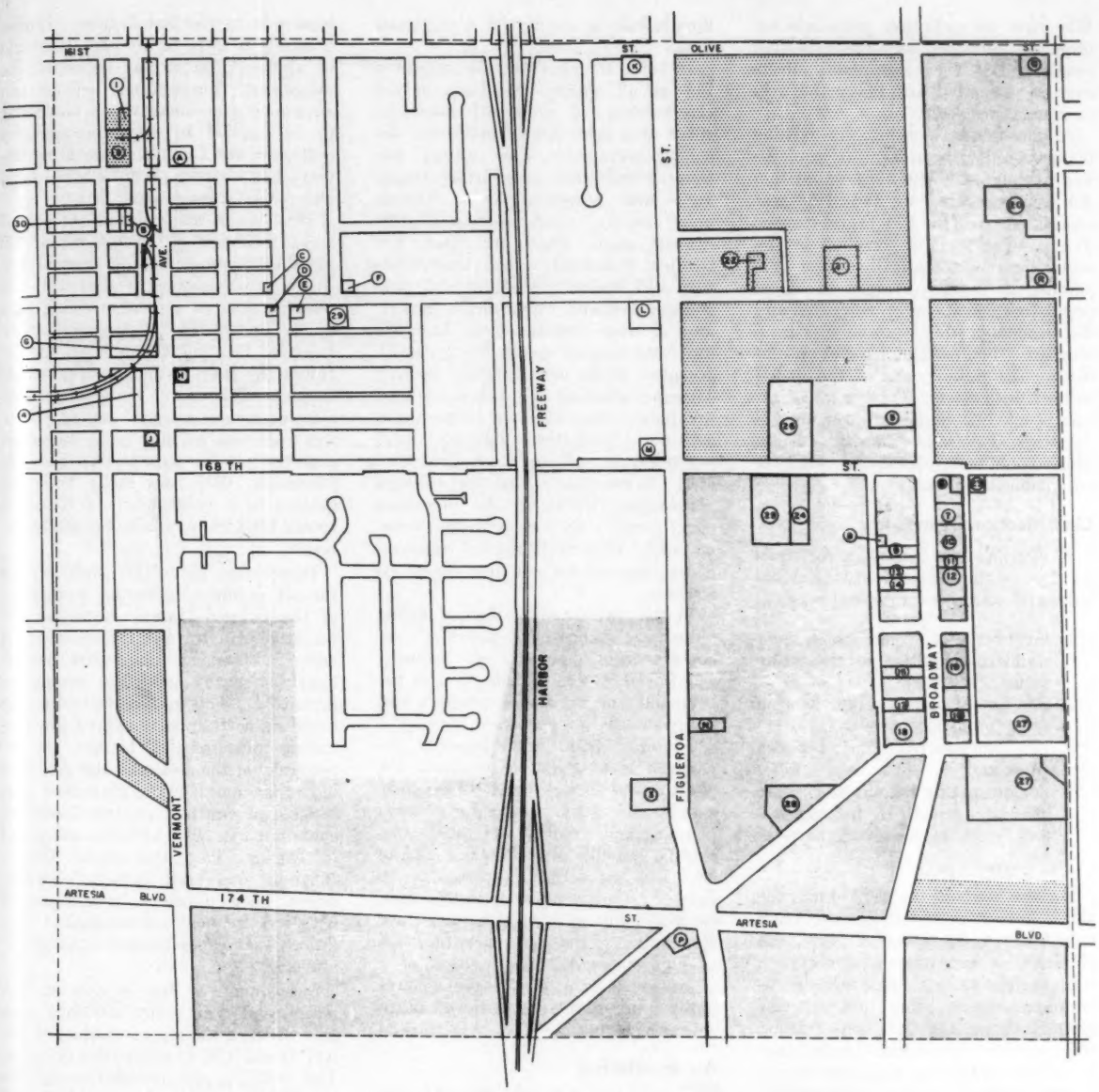


Fig. 3. 1958 Sources and Zoning APCD Grid 37-22

within the Basin is needed. This study offers resident (night-time) population density computed from equal land areas of one square mile. Past and present density levels could serve as guides in estimating the future density.

Since forecasting the pattern of any human endeavor is a hazardous venture, the future density should be periodically evaluated in the light of changes which will occur. It is our opinion that the population distribution will be the most easily projected parameter which can be converted to other desired factors.

Given the potential urban area and knowing the future population density, we would be able to estimate the future population. In turn, by use of per capita relationships, future land use by classification can be estimated. Further, this can be converted into the future air pollution source emission. When the meteorological study has determined the atmospheric dilution capacity and the public health people have set community air standards, the saturation limits can be calculated.

Whenever air pollution potentials for proposed industrial uses are requested from the APCD, the probable effects can be estimated and reasonable recommendations made.

A pilot study showing the existing population density in terms of isopleths was attempted. The 1954 population dot map prepared by the RPC was superimposed on the APCD grid system. The population dots corralled in the unit grids automatically gave the population density. Lines of equal population density were delineated and the Isodemic Map shown in Fig. 5 resulted. The resident population represents the initial point of the home-to-work auto travel. Further investigation would be desirable to map the day-time population density pattern which would be helpful also in a study of automobile traffic emission.

Classification of Industry

A classification system is essential to cope with the myriad individual industrial concerns for several reasons:

1. For ease of communication a standard definition of the many industries is needed,
2. For ease of human comprehension and administrative control,
3. For comparative study between cities, and
4. For estimating current and future industrial growth by indirect factors such as industrial employment.

For the needs of the MIZ study, the air pollution potential of the basic industries may be expressed in the form of single or multiple index numbers. Some insight as to a single index number approach to this problem was gleaned from the job classification technique used by personnel technicians in private enterprise and government service. On the basis of a conference with the head of the classification section of the Los Angeles County Civil Service Commission, it appears that our classification system would entail a more difficult task than theirs. Each process would be classified through a point rating system according to the specific contaminants (toxicity, nuisance), and the source-distance effect. The air pollution indexes from these processes will then be related to the major activity of the various industrial use classifications.

Another approach is the use of multiple index numbers. Whenever an industry exceeds the set numerical standards for any air pollution factor, then it fails to qualify for a particular zone.

In 1951, Dennis O'Harrow suggested the use of specific standards in the classification of industrial uses, instead of a mere list of industries, for zoning purposes.[8] This system was termed "industrial performance standard" and weighed eleven factors: noise, smoke, odor, dust and dirt, noxious gases, glare and heat, fire hazards, industrial wastes, transportation and traffic, aesthetics, and psychological effects. Of the eleven factors, four of them (smoke, odor, dust and dirt, and noxious gases) are generally accepted to be air pollution factors. To some extent air pollution is involved in other factors such as traffic (auto exhausts), aesthetics (visibility), and psychological effects (eye irritation, etc.). It was pointed out that through performance standards the industries could improve their classification automatically when technological improvements removed some of their obnoxious features.

In the traditional method of listing industry, ossification generally occurred—once classified, an industry was frozen to that classification at the beginning of a zoning program and rarely changed thereafter.

To date little administrative experience is available to evaluate the effectiveness of industrial performance standards. After a discussion with planning and building and safety specialists, possible pitfalls were found to be: lack of technical personnel to quickly process complex industrial uses, the possibility of substituting arbitrary standards for the older arbitrary list of industries, and the creation of a false sense of security relying on a newer but yet untested method by a metropolitan agency.

Air Monitoring

No particular technical difficulties are expected in the air sampling phase except for the location and number of stations. A dense network of stations should be initially established and duplicating stations eliminated later. These stations would be in addition to the existing air monitoring stations established for emergency measures.

Zoning Experiments

If the sum of the limited experiences to date can be legitimately extrapolated, we can expect that either the present substantiating data and expert opinions available are not convincing enough or more effective informational activity is needed.

Some zoning authorities have discouragingly stated that the Los Angeles Basin area is beyond repair through the zoning process due to the near impossibility of removing existing extensive industrial installations. Hence, if zoning is to be of any use, it should be applied prior to any industrial development. Interestingly enough, an air zoning experiment which failed was to be applied to an unincorporated portion of the County where urbanization has barely begun—the Agua Dulce-Mint Canyon area.

This latter area, which is located amid mountainous terrain about 30 miles to the northwest of central Los Angeles, was being studied for the establishment of a precise zoning plan by the staff of the Los Angeles County Regional Planning Commission (RPC). Due to the desire of the property owners in the area to remove the several years-old restrictive interim zoning, there was considerable movement to adopt a precise plan as soon as possible. By December, 1957, this study had progressed to a point where a tentative zoning plan was available for consideration.

In response to a RPC staff request for air pollution potential evaluation of the industrial areas shown on the tentative plan, the APCD recommended early in January, 1958, that neither light nor heavy industrial zoning be permitted. This recommendation was based on a study that related the prevailing meteorological factors, the topography of the area, and the proposed industrial zones which permitted uses capable of emitting uncontrollable air contaminants. The area was compared to Donora, Pa.; the Meuse Valley, Belgium; and Trail, British Columbia, where smog disasters have occurred with less frequent meteorological conditions that cause limited atmospheric diffusion.

Subsequent to the receipt of this recommendation, many meetings were held between the representatives of the APCD and RPC to resolve this problem. The APCD's recommendation against industrial zoning had to be balanced against the RPC's desire to provide a balanced community with local industrial employment opportunities.

Control by the Zoning Ordinance

As a possible solution the RPC Director of Planning desired the creation of a new industrial zone which would permit industries of a non-air pollution type. At his request, the representatives of the APCD agreed to formulate a list of industries which would be non-critical from the air pollution standpoint.

One of the first steps was the partitioning of the possible pollution sources into three groups: (I) not permitted, (II) conditionally permitted, and (III) permitted. The 1263 different types of basic equipment requiring air pollution permits* were evaluated as to

* It should be kept in mind that although certain types of equipment require operating permits from the APCD, those permits by no means infer that control devices exist.

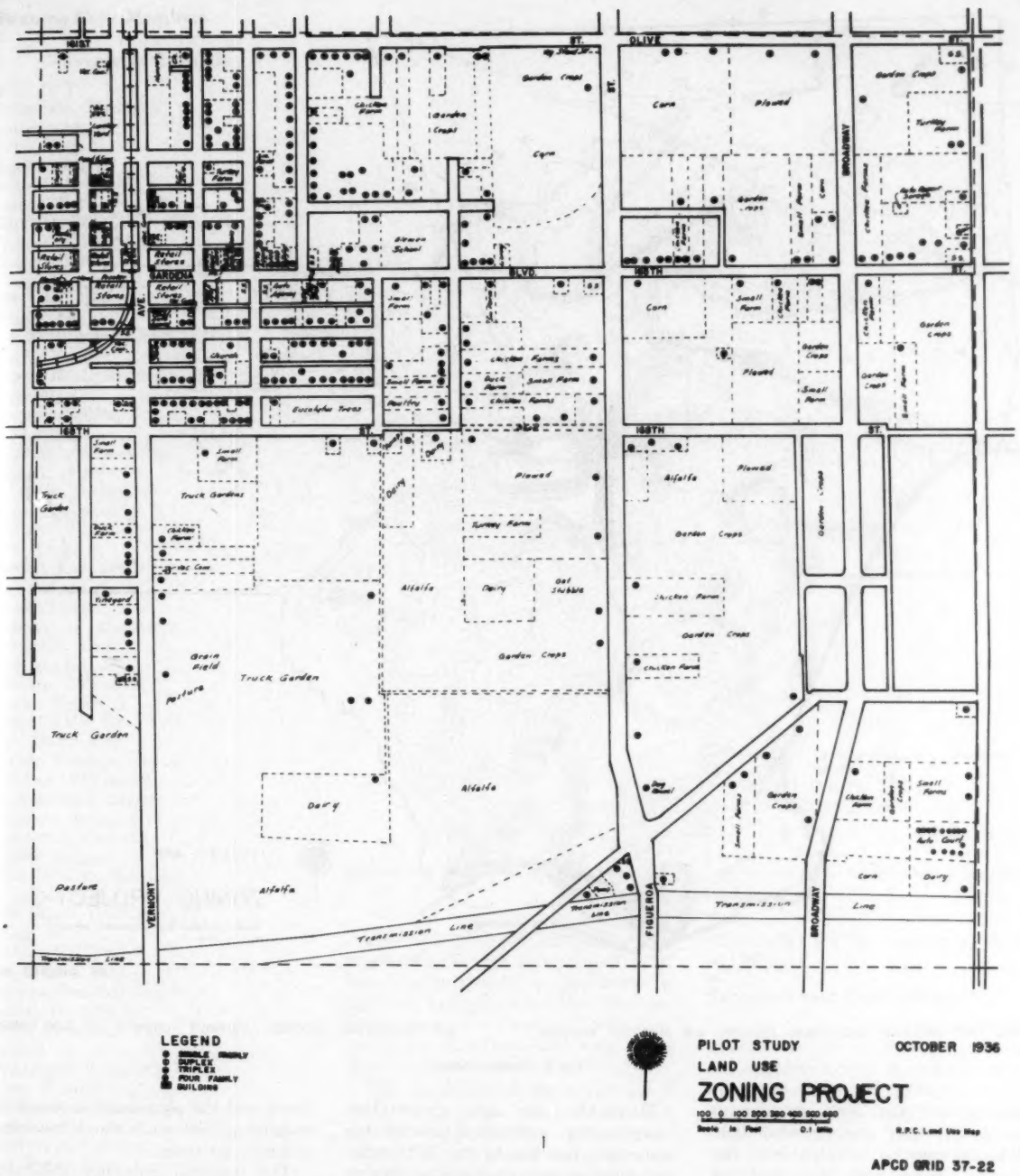


Fig. 4. 1936 Land Use APCD Grid 37-22

the degree of air pollution hazard from their use and were classified as follows: Class I: 393, Class II: 222, and Class III: 648. Since there was more equipment permitted than prohibited, it was decided that a "prohibitive" type of regulation would be the more convenient form—that is, equipment not specifically prohibited would be permitted.

In view of the general spread of air pollution problem uses through several zones, it was decided to create an overlay zone which could be used to blanket the area subject to restricted atmospheric diffusion. In this manner the overlay zone would screen out uses undesirable because of air pollution potentials and yet would allow a choice of basic zones. Thus, the initial air pollution zone classification called Zone MC (Mountain Canyon) was changed to Sub-Zone APC (Air Pollution Control).

Since many of the devices on the list of prohibited basic equipment could be employed in either air pollution or non-air pollution uses depending on the process, a more compact list of 92 undesirable processes was prepared. In turn, the 92 processes were further consolidated (especially the chemical processes) into 22 prohibited industrial uses. Accessory and non-production types of processes were permitted in limited quantities so as not to eliminate

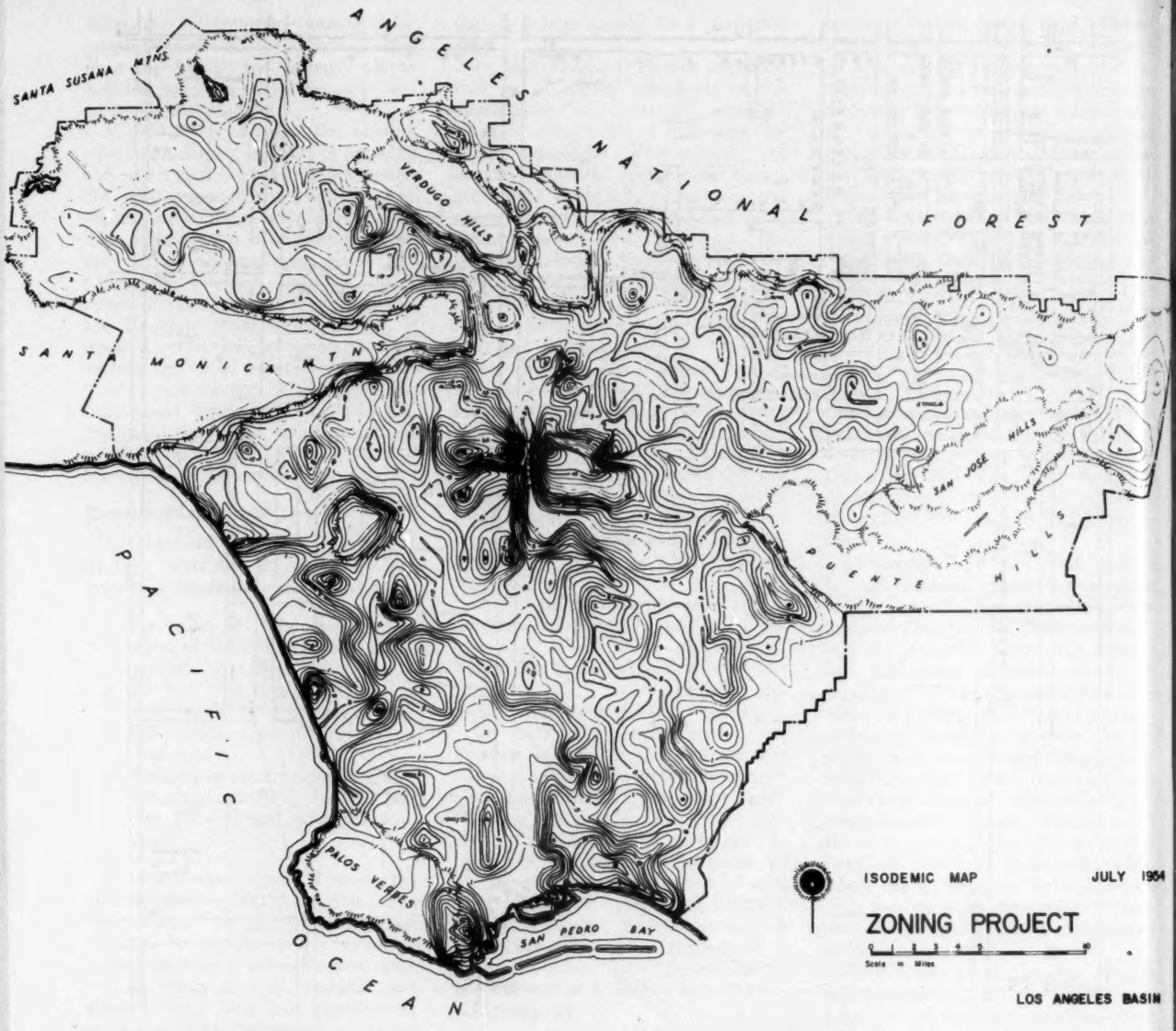


Fig. 5. Isodemic Map

minor air pollution emission sources. The APCD also recommended that residential uses be excluded from the industrial zones and that fuel oil burning be limited (subsequent to this, Rule 62 was adopted concerning fuel oil burning which eliminated the necessity for this limitation).

As a test of the restrictiveness, the effect of the proposed regulation on reducing the number of permitted uses in the Light Manufacturing Zone (M-1) was analyzed. It would serve no purpose to call a zone industrial and then eliminate all the industrial uses with a sub-zone restriction. The analysis showed that the restriction did not remove all the permitted uses in Zone M-1 and yet would remove the undesired air pollution sources.

Meanwhile, the Agua Dulce-Mint Canyon plan was recommended for immediate approval by the RPC without delaying the entire zoning district for the creation of the air pollution sub-zone. In their findings the RPC recommended that further study be made when the air pollution problem becomes evident in the future. In turn, the legislative body adopted the zoning plan as proposed by the RPC despite the request of the APCD for delay until the sub-zone could be adopted.

The probable reasons for overiding the APCD's request were the delay in the creation of the sub-zone, the insistence of the citizens for a zoning plan immediately, the apparent lack of unfavorable meteorological conditions, and the piece-meal approach by restricting this area without restricting other similar areas.

The proposed Sub-Zone APC was later presented to the RPC for discussion and possible adoption as a zone classification. While no unanimous RPC decision was made, from the comments of the individual commissioners, it was inferred that a County-wide air pollution zoning regulation by the APCD was needed.

Industrial Zoning by Rule

Because of the RPC's viewpoint, the APCD prepared a rule (proposed Rule 65) which would accomplish the desired effect. The County was divided into four major areas: Antelope Valley, Mountain Valley, Basin Valley, and Basin Plain (Fig. 6).

Welcome New Members

INDIVIDUAL MEMBERS

Aepli, O. T.
Wyandotte, Michigan
Anderson, A. A.
Provo, Utah
Angeli, John C.
Fenton, Michigan
Atwood, J. D.
Gallipolis Ferry, West Virginia
Bahnfleth, Donald R.
Chicago, Illinois
Beaton, Kendall F.
New York, New York
Benline, Arthur J.
New York, New York
Bockno, G. C.
Marcus Hook, Pennsylvania
Briggs, R. A.
Charleston, West Virginia
Busch, E. J.
Pittsburgh, Pennsylvania
Clayton, Wiley
Memphis, Tennessee
Crepea, Seymour B.
Madison, Wisconsin
Ettre, Leslie S.
Norwalk, Connecticut
Fair, Donald H.
Amelia, Ohio
Faulkner, Jr., Donald M.
Richmond, Virginia
Ford, Jr., Ben R.
Berkeley, California
Gedeon, Ernest R.
Niagara Falls, New York
Hale, Malcolm M.
Chicago Heights, Illinois
Hamilton, William R.
Los Angeles, California
Humphris, Leonard W.
Melbourne, Australia
Kettner, Helmut
Berlin-Dahlem, Germany
Lawrence, P. H.
Long Beach, California
Lorenz, M. C.
Ventura, California
Marshall, H. Borden
Toronto, Ontario, Canada
Martin, Jr., John G.
Danville, Virginia
McGuire, A. P.
Long Beach, California
Milon, William H.
Pittsburgh, Pennsylvania
Mouwen, Herman C.
Rahway, New Jersey
Neil, Frank M.
Houston, Texas
Nishimura, Yoshikazu
Tokyo, Japan
Reiter, William M.
Philadelphia, Pennsylvania
Revoir, William H.
Newington, Connecticut
Ringler, Marvin D.
New York, New York
Ruud, Robert P.
Monrovia, California
Sanborn, Robert A.
Somerville, New Jersey
Scott, William E.
Perkasie, Pennsylvania
Smith, Jr., Robert D.
Phoenix, Arizona

(*Continued on page 173*)

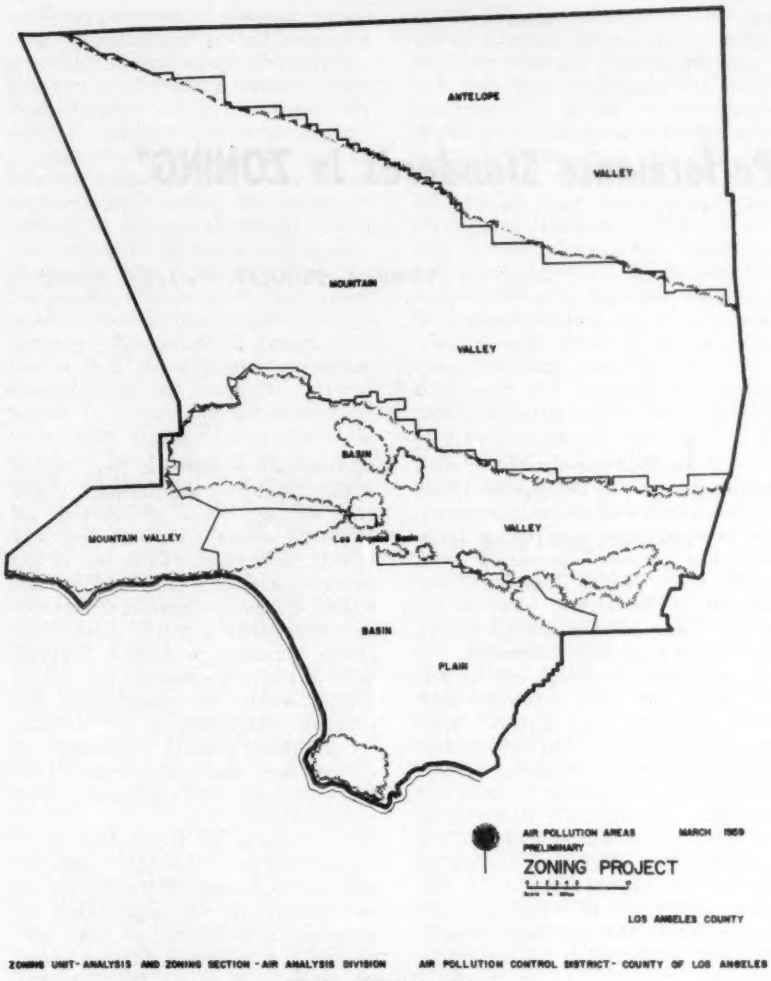


Fig. 6. Air Pollution Areas

This Rule proposed that undesirable processes which had not yet located in Los Angeles County be prohibited in the Basin Valley Area and the Mountain Valley Area. Further, provisions similar to the Sub-Zone APC were to be applied to the Mountain Valley Area.

This proposed Rule has never passed the drafting stage, since it was felt that it was necessary to gather more substantiating data before applying an industrial zoning plan to the entire Los Angeles metropolitan area. It was the belief that the time required for this study would not be so lengthy that the uses in the Mountain Valley Area could not be restricted before a major catastrophe develops.

From this experiment we have learned that an air zoning program will be difficult to establish in an area not yet reaching the threshold of obnoxiousness. The antithesis is that once an area is industrially developed it will be difficult to roll back zoning to remove offending industry. It appears that timing becomes crucial—not too early, yet not too late in the industrial development—for the application of the MIZ Plan.

Summary and Conclusion

1. As population and industrial growth continue in large urban areas, the cumulative effect of multiple sources or an area source will rapidly become an air pollution problem. This problem evolves since no source control device can be economically engineered with 100 percent efficiency.

2. For areas with a potential toward urbanization and subject to limited natural air dilution capacity, industrial zoning could be legally used as a supplementary control aid provided it is based on rational reasoning and facts. It is suggested that the main rationale be the atmospheric dilution capacity.

3. The jurisdictional area for the air zoning regulation should be coterminous with those areas related by a common air pollution problem. Currently, it is proposed that these zoning regulations be applied on a metropolitan

(*Continued on page 174*)

Performance Standards in ZONING*

ERWIN E. SCHULZE, Stevenson, Conaghan, Hackbert, Rooks, and Pitts, Chicago, Ill.

In 1858 not one of the cases decided that year by the Supreme Court of Illinois dealt with planning or zoning. One hundred years later zoning problems had become the single most prolific source of civil litigation on the calendar of the highest court in the state. There is no reason to believe that Illinois is unique in this respect.

It is apparent then that lawyers and the courts are much concerned with zoning problems. But obviously, they are not alone. Zoning and metropolitan planning, virtually unheard of a scant 30 years ago, are familiar terms to our elementary school set. Everyone is concerned about zoning and a quick glance at the Municipal Ordinance Review for 1958 published by the National Institute for Municipal Law Officers would indicate that virtually everyone is trying to do something about it.

In the rush to rezone and rehabilitate our existing metropolitan areas and to plan presently undeveloped areas for the tremendous expansion which we are told lies ahead, it is understandable that new and different tools with which to accomplish the job would be eagerly sought and accepted. It is understandable, too, that the *avant garde* of our professional planners would be advocates, and rightfully so, of what they believe to be the new and modern way.†

In the field of industrial zoning, "performance standards" on such subjects as noise, vibration, smoke and particulate, toxic and noxious matter, odorous matter, glare and heat, among others, constitute the planners' bright and shining dream of creating an industrial utopia. Here at last is a vehicle upon which to ride out of the primitive stage of zoning right into the future—by the specification of performance rather than in specific descriptions of use, materials, or methods. Translated into zoning parlance, they would control within set specifications the nuisance characteristics of industry rather than allocate industries to different zone classifications based upon the traditional, and apparently time worn, use lists.

The purpose of this article is to suggest that in our anxiety to improve ourselves by casting off the old use list and putting on the new mantle of performance standards, we may well be repeating, albeit in different terms, an error as basic as the fallacious assumption that a higher class use, i.e., residence, was always an acceptable use in a lower classification, i.e., manufacturing. A limited amount of experience with typical standards, a prolonged contact with engineering friends and some deep concern with the law indicate to the writer that a reappraisal, or appraisal, if you prefer, is in order.

Function and Use of the Standards

Under the theory of performance standard zoning, any type of industrial use is permitted in any industrial zone provided only that it meet the standards established for that district. It thus becomes mandatory under the theory that specific standards be set—numbers with which to evaluate the conduct of industry. Under this mandate it should follow that the state of the science be such that precise standards can in fact be set. As will appear below there is considerable evidence indicating that at least in some fields the state of the science is not so far advanced.

In every application for a building permit it must be alleged that the installation when completed and operating will comply with the performance standards. The Chicago ordinance and most similar proposals specify that the Zoning Administrator is entitled to rely upon a certification of ability to comply signed by a registered architect or structural engineer. The two years of "experience" under the Chicago ordinance has consisted solely of the issuance of building permits based upon this type of certificate.

Whether or not one believes that every registered architect or structural engineer is competent to evaluate or predict future field conditions based upon a set of blueprints, it is at once apparent that some such device as the architect's certificate is necessary in order to make the ordinance administratively feasible. Even assuming such predictions can be made (again, there is evidence to the contrary) it was a choice between such a device of blanket acceptance or referral of every application to not one but several outside consulting firms for scientific advice or evaluation which could not reasonably be furnished within a building department.**

This brings us to the heart of the problem. Under the performance standard type of ordinance, a building permit will issue virtually as a matter of routine. It is only after construction and the plant is in operation that performance standards come into their own. If the plant doesn't comply at all times with each and every standard it is, under the law, subject to fines and imprisonment (in Chicago, $200 per day of violation and six months) and also, and more importantly, the use becomes nonconforming; an ugly word in zoning, for nonconforming uses established after the effective date of the ordinance are not permitted to exist and are subject to immediate abatement. Assume, for example, that odors emitted from a plant when detected at the lot line require five volumes of clean air, rather than four, to be eradicated in a dilution test

---

* Presented at the 52nd Annual Meeting of APCA, June 21–26, 1959, Statler Hotel, Los Angeles, Calif.

† That this general observation may have overtones considerably broader than the subject of this paper is discussed by Blucher under the title "Is Zoning Wagging the Dog?," *Planning* (1955).

** In the recent proposal for Porter County, Indiana, it is specified that the certificate must be from a "scientific laboratory." The technical consultants are thus written into the law.

* even after the installation of odor control equipment in accordance with the application for a building permit. Or, assume, that after certification of your ability to comply, uncorrectable steady state vibrations from the plant having a frequency of 32 cps cause a displacement of 0.0002 in. at the nearest Residence District boundary line. Under these circumstances the plant is nonconforming, is subject to fine and abatement and, what may be worse, it is by law declared to be a public nuisance per se, subject to injunction by suit of a private citizen.

That this circumstance should exist under performance standard type zoning laws is at once unfortunate and unavoidable. The theoretical argument against the use list is that it had no control over changes in uses once established. What was once an unobjectionable use might be converted to an objectionable one—thus, down-grading the neighborhood without violating the zoning law. To meet this threat it is necessary that the performance standard in the zoning law operate prospectively so as to prevent the undesirable change from occurring. We must recognize, then, that performance standard zoning is inherently more concerned with regulation than it is with the initial placement of industrial activity in a proper zoning classification. Whether the latter goal might not better be served by the more conventional use list and the former by a properly designed regulatory ordinance is the basic question propounded herein.

Experience Under Performance Standards

The new Chicago Zoning Ordinance adopted in May, 1957, is the first zoning ordinance in the country applying a full scale of performance standards to industrial zoning for a large urban area. Original drafts of the ordinance were first circulated in Chicago and throughout the country in October of 1955. The drafts contained both the test and the zoning maps. As is customary, almost everyone was concerned with the maps and literally no one with the text. Contrary to the common understanding,† the manufacturing section of the Chicago ordinance did not evolve by use of the conference method of drafting legislation. By conference method is meant a procedure whereby all affected parties—planners, governmental agencies, business, industry, and the public—sit down to consider and revise a piece of legislation prior to its introduction into the legislative body. The failure to successfully utilize the conference method in the manufacturing section stems primarily from a general apathy to zoning and from the extremely complicated nature and the obtuse significance of the performance standard concept. For whatever reason, the fact is that the original performance standards did not come into critical review by competent industrial engineers until shortly before the date scheduled for the passage of the ordinance and their position was not made known publicly until the day before the ordinance was to pass. At that point a storm of industrial protest, as has never been raised before in Chicago against any piece of legislation, was unleashed and the passage of the ordinance halted. From that point on the technical experts of industry and the City sat down to work out "compromises" which finally resulted in the passage of the ordinance on May 29, 1957. It can be safely said that neither side was happy with the end product. Probably the most salutary change was the exemption of existing uses and the complete deletion of a performance standard on smoke and particulate and a reference simply to the existing law on that subject.

It was the thought of all concerned that the performance standards would be under constant review and changes made where necessary as indicated by experience in performance and enforcement. Unfortuntely, while construction has continued at a rapid rate in Chicago (under building permits granted pursuant to the ordinance) the fact is that there has not been a single prosecution nor for that matter any attempt to enforce the standards against operations subject to them. According, as of today, two years' experience in Chicago under the ordinance has taught us nothing about how performance standards function.

In the debates in Chicago over the new ordinance it was claimed by some of its advocates that the performance standards were "tailor-made" for Chicago. Interestingly enough, the original proposals which received nationwide circulation in 1955 and 1956 have been copied, virtually word for word, in other smaller ex-urban or rural communities. Currently we are considering for Cook County, Illinois, a proposal with only slight variations on the Chicago theme. Porter County, Indiana, has before it a proposal which has been described as "an improvement on the Chicago ordinance" or, in more precise language, an ordinance containing more restrictive performance standards than those contained in the Chicago ordinance. It is the writer's understanding that comparable proposals in substantially the same form will soon be presented in New York City and Minneapolis. In other words, the performance standard concept is beginning to sweep the country. Before we get swept along with it, it behooves us to examine the precedents for what may be proposed for your city of tomorrow. What is said below in the scientific arena should be understood to be the statements of a non-engineer who has merely observed and heard the debates of scientists on the subject.** Full responsibility will be borne for the observations on the law.

Some Basic Legal Principles

Most of the existing legal precedents pass on the validity of use list type zoning ordinances. Consequently, they shed little light on the constitutional issues which are raised by the introduction of performance standards into zoning. It is possible, however, to draw some basic principles from the decided cases. First, at least so far as Illinois is concerned, there is no reason to believe that the Supreme Court will not continue to review aggressively the propriety of the application of the zoning law to specific property.[1] In the field of zoning, courts seem relatively more willing to impose their own view of the propriety of the ordinance as applied and relatively unwilling to defer to the legislative or administrative judgment.[2] Second, each case will continue to be decided largely on the basis of its own peculiar fact situation.[3] Finally, the basic substantive due process principle will continue to have general application: that the ordinance must bear a substantial relationship to the permissible objectives of police power legislation—that is, the ordinance must have a reasonable relation to public health, safety, morals, and the general welfare.[4] Stated in the negative, the ordinance must not deny equal protection of the laws; must not be arbitrary or capricious nor unlawfully discriminatory.[5]

Inasmuch as performance standards are so closely related to nuisance type regulatory ordinances, we can also look to cases in the nuisance field for precedents. These decisions are helpful by analogy to predict the type of treatment that will be given performance standards in a zoning law. The basic approach underlying the performance concept is to regulate offensive activity. This, of course, is also the objective of nuisance law. Performance standards differ from nuisance standards only in

---

* Note that the performance standard pays no attention to the infinite complications of testing for odors.

† In all fairness to the draftsmen, it should be noted that it was their desire to seek and obtain the advice and counsel of all interested parties. It is unfortunate that this desire was not realized.

** It should be pointed out that many advocates of performance standard zoning have a similar lack of technical training in one or more of the several fields encompassed by them.

degree—seeking to achieve the same objective, but by means of detailed "scientific" measuring criteria rather than the historically vague language of the law of nuisance. It should be kept in mind that in a performance standard zoning law, any activity which exceeds the standards is declared a public nuisance per se. In this situation the existence of the nuisance is "proved" by the violation—there is no need for the introduction of other evidentiary facts such as damage, cost to repair the damage or to control the nuisance, value of the industry to the public, condition of the surrounding neighborhood, and other matters customarily used by the courts in common law nuisance cases "to balance the equities."

The classic statement of the legislative power to make the determination of what is a public nuisance is found in Laugel vs City of Bushnell[6] in which it is said.

> "Nuisances may thus be classified: First, those which in their nature are nuisances per se or are so denounced by the common law or by statute; second, those which *in their nature are not nuisances* but may become so by reason of their locality, surroundings, or the manner in which they may be conducted, managed, etc.; third, those which *in their nature may be nuisances*, but as to which there may be honest differences of opinion in impartial minds.
>
> "The power granted by the statute to the governing bodies of municipal corporations to declare what shall be nuisances and to abate the same, etc., authorizes such bodies to conclusively denounce those things falling within the first and third of these classes to be nuisances, but as to those things falling within the second class the power possessed is only to declare such of them to be nuisances *as are in fact so.*" (Emphasis added in part.)

The categories laid down in the Laugel decision have been used by the Illinois courts to judge nuisance ordinance cases since that time. The only contra authority is *obiter dicta* appearing in the Dube opinion in which it was stated that the law may regulate if "an act or thing is of such nature that it may become a nuisance or may be injurious to public health if not suppressed or regulated." The court, however, in that decision went on to find that the metal fabricating operations involved were in fact nuisances as presently conducted. On this basis the Dube opinion is ambiguous. If the Laugel criteria are continued in full force in the face of the Dube dicta, it follows that the proposed performance standards have before them a sizeable constitutional hurdle when they are applied to conventional industrial activities falling in the second category. This does not mean to say that industrial activities which are common law nuisances in fact may not be regulated or prohibited, but only that regulation by numbers may not meet the constitutional test when applied to an activity which would not otherwise be a common law nuisance.*

The Requirements of Substantive Due Process

It appears to the writer that at the present state of scientific knowledge certain qualities of the proposed performance standards tend to raise substantive due process objections. The objections run along these lines: performance standards are arbitrary in many respects; they tend to be unnecessarily harsh in some respects; and certain of them tend also to be inherently discriminatory. These objections exist quite apart from the constitutional objection already mentioned.

The ultimate aim of performance standards is to prevent the conduct of activities in a manner offensive to human beings and their economic affairs, by the imposition of detailed, scientific performance regulations. For this purpose it follows that if arbitrariness is to be avoided, there must first, be a scientifically valid means of measuring the physical phenomena and there must second, be a scientifically known and accepted level of the phenomena which adversely affects human beings or their affairs in some way. If both these conditions are not met, the standards are arbitrary regardless of the fact that they contain a host of detailed and superficially precise numbers and formulae. Furthermore, if both conditions are not satisfied, it is questionable whether it can be shown that the standard has a reasonable relation to public health, welfare, morals, and safety—a necessary showing for the validity of the ordinance.[7]

Noise

Several of the proposed standards appear to fail to meet both of the so-called scientific conditions. The noise standards are established in terms of decibels at given frequencies to be measured at residential and business district boundary lines. The vibration standard is a little more complicated. The levels are in terms of displacements to $^1/_{10,000}$ of an inch in given frequency ranges for three different types of vibrations. They are to be measured at the lot line and at the residential and business district boundary lines. To some extent the standards vary as between industrial zones. In these fields there is scientific instrumentation which permit the measurement of both phenomena, although there seems to be some debate as to whether vibration measuring devices are sufficiently standardized as yet. However, it can be stated quite broadly that there is little data to support the levels established on a community annoyance basis. The determination of annoyance levels which these standards purport to represent involves many psychological factors. The science itself is properly termed psychoacoustics. One of the leading authorities in the field has concluded that "the establishment of clear-cut criteria or tolerance levels is at present a goal rather than an immediate possibility . . ."[8] If this is so for tolerance levels it must also be so for the establishment of annoyance levels. Leading journals in the field contain no new revelations which would suggest that levels can now be set where they couldn't have been several years ago.

The noise levels first proposed in drafts of the Chicago ordinance and subsequently copied in other ordinances and proposed in still others were based upon the so-called Chicago Noise Survey conducted by Armour Research Foundation of the Illinois Institute of Technology during the period 1947–51. The survey consisted of plotting in graph form the decibel levels of the sounds of Chicago—in all communities. There was no attempt whatever made to determine the subjective response of individuals to those sounds. The report of that survey suggested a limiting spectrum for industrial noise which was considerably higher than that contained in the original Chicago proposal. The reduction in the decibel levels was rationalized by the proponents of the ordinance (not the Armour scientists) on the simple basis that the spectrum suggested by the Armour survey was "too high." By making a given percentage of Chicago industry incapable of meeting the standard, conditions, presumably, were to be improved.

Vibration

In marked contrast to the empirical approach to the noise standard, the author of the proposed vibration standard in Cook County has stated that the levels established constitute an average of the tables found in the three published papers on the subject of human response to vibration. Two of these papers are by Americans; the third, not available in translated form, reports tests conducted in Germany in

* It would appear that the law of California may be to the contrary. See, Dobbins vs. Los Angeles 139 Cal. 179, 72 Pac. 970 (1903).

1935. All three record responses of a test group to vibratory exposure under laboratory conditions. In one of the American articles it is concluded that the tests were interesting but that further work is indicated.[9] The author of the current Cook County proposal has used the spectrum formed by the three tables as the basis for distinguishing between the industrial zones, which, happily, also number three. The bald use of this kind of data is somewhat akin to taking the Bosanquet-Pearson formula for theoretically determining ground concentrations of sulfur dioxide under assumed conditions and writing it into law.

Theories evolved in the laboratory or based on empirical test data such as used by Armour may provide useful and scientifically valid "rules" for experimentation, testing, and analysis. It is a tremendously significant step, however, to move from this posture to a position (as in performance standards zoning) where a violation of the "rule" invokes criminal sanctions. Lacking a scientific background it is most difficult to make qualitative judgments in these highly technical fields. But from what has been presented quantitatively, it appears to this writer that in neither the noise nor vibration category is there sufficient scientific knowledge to support the levels established in the face of the challenge that they are, as a matter of law, arbitrary and capricious.

Odors

In the field of odorous matter, dilution tests of volumes of air at the lot line are the criteria established. While dilution testing methods have obtained some reliability the touch stone in this field is the procedure and method of testing. Elaborate safeguards to avoid psychological factors, health variables, etc., and the use of qualified panels of sniffers are necessary. This may be feasible in a large industry vitally concerned with fine variation in the concentration of odors or in a consulting laboratory. It may not be appropriate for enforcement by the building department of the ordinary governmental unit. Further, there appear to be no studies whatever to suggest that individuals are offended when they are capable of detecting odors which become odorless when diluted in 1, 4, 8, or 20 parts of clean air. In this field the proponents of the odor standard operate on the thesis that no odors should emanate from an industrial operation. Without debating the socio-economic implications of this position, it might be safely said that there is a grave question as to how such an argument would appeal to a court.

This leads us to a final, general observation concerning performance standards in the fields of noise, vibration, and odors. Clearly one of the constitutional facts* to be developed in the inquiry by the court into the propriety of the standards, is the method of establishing the levels themselves. To meet these levels, industry will suffer an economic burden. This is perfectly all right, and legal, provided that there is a concomitant benefit to the public. In other words, the standard is justified by a showing that there is a significant reduction in annoyance to the public. To date there have been few, if any, such demonstrations in defense of the standards on these grounds.†

The field of air pollution is unique in several respects when compared with the other standards. First, scientific instrumentation, such as it is, has been in use throughout the country over a period of years. What's more, it has been upheld by the courts. Second, we have had a long history of regulatory ordinances establishing standards for enforcement which have likewise been upheld by the courts.[10] Thus, the state of the science seems sufficiently advanced to establish and enforce community annoyance levels. If there is to be objection to the use of the levels proposed for the performance standard, it is on the basis that they are unreasonable, i.e., unnecessarily restrictive or unlawfully discriminatory. Both these nonscientific conditions need examination. A point should be made clear at the outset—there is no question but that in good planning and zoning careful attention must be paid to the air pollution potential of the proposed uses in any given area. The problem here is whether the performance standard is the best available zoning tool for this purpose.

Instead of utilizing established and accepted standards, the typical air pollution performance standard has to date used two novel limitations in attempting to restrict the emission of smoke and particulate matter. The first, for smoke, is in terms of a "smoke unit."** The second, for particulate matter, is in terms of "pounds per hour per acre from all sources on the zoning lot." The concept of the smoke unit is a considerable refinement in the use of the Ringelmann Chart. If the Ringelmann Chart itself is an imprecise measure of the density of smoke it would seem that this further refinement would merely compound the possibility of error in the use of the Chart. For example, at the recent University of Wisconsin clinic on air pollution it was stated that a "reasonable" variance of as much as one Ringelmann number was to be expected among evaluations of the same stack made by different smoke inspectors. Considerably less variation among observers would cause difficulties with the proposed standard under which the maximum emission must average less than 0.5 Ringelmann/hr.†† The concept of a restriction on particulate matter in terms of pounds per hour per acre is explained on the grounds that it has a relation to the amount of land utilized and therefore represents a zoning approach to air pollution control. The difficulty here is that for the limitation to be meaningful a number of assumptions must be made. The principal one in Cook County is that the average plant size is 25 acres. Thus, any plant with larger acreage is benefited under the standard and any plant with smaller acreage is penalized. Query as to the overall reasonableness of this approach.

On the question of unlawful discrimination, there would appear to be essential differences between an air pollution standard and the other standards. The standard on noise, vibration, and odors regulate the nuisance characteristics of the industry in the particular area in which it is found, especially as it affects adjoining business or residential districts. In a large urban area noise and vibration in one section will have little bearing on the ambient noise and vibration in a neighborhood a mile or two away. This is not true with respect to air pollution. There is no single source of air pollution in any community. The problem is community-wide and varies in its characteristics from community to community. Weather and topographical differences make Chicago's prob-

---

* By 1937 the Supreme Court of the United States had pretty well discarded the application of substantive due process principles to federal economic regulatory legislation. Most state courts, however, have continued to apply vigorously substantive tests in economic due process situations. See, Paulsen, *The Persistence of Substance Due Process in the States*, 34 Minn. L. Rev. 91 (1950); and Comment, *Substantive Due Process in the States Revisited*, 18 Ohio S.L.J. 384 (1957).

† This could be caused by one of several interestingly inconsistent explanations: (1) that the performance standard concept has not heretofore been attacked and accordingly has not required defense; (2) that such demonstrations have not been made because they could not be; and (3) that such demonstrations have not been required because the standards are reasonable on their face. A descending scale of preference is indicated.

** A smoke unit is defined as the number obtained when the smoke density in Ringelmann number is multiplied by the time of emission in minutes.

†† In Cook County, 10 units are proposed for M1 Districts, 15 for M2, and 25 for M3. On a comparable basis for light industry, this is one-tenth the amount of smoke permitted under the Pittsburgh, St. Louis, and Los Angeles ordinances.

lems unlike those of other cities. Thus, an air pollution performance standard meets only incompletely the community air pollution problem. Further, the standard purports to make distinctions between the three industrial zones. There appears to be nothing to justify a distinction between one boiler with the same automatic controls using the same fuel from another in a different industrial zone. Yet the performance standard may be such as to make one legal and the other nonconforming. The manner of controlling air pollution is not inherently or essentially a zoning problem. It is rather, a regulatory problem which can best and only be met in a comprehensive regulatory ordinance.* When that day comes in which it is feasible to control the nuisance characteristics of industry by the use of performance standards in zoning laws, the standard for smoke and particulate matter should, at best, be a mere reference to the existing comprehensive law on the subject.

The Problem of Procedural Due Process

Quite apart from the substantive issues of the propriety or reasonableness of the performance standards is the question whether a zoning law basically designed to facilitate the proper location of various uses within an area pursuant to an established plan of that area is by nature or experience adaptable to the requirements of procedural due process. There is, of course, one simple answer. It is that the zoning law can contain any type of administrative or enforcement provision which is constitutionally required. The problem of procedural due process is not as to what the law should contain in order to comply with constitutional safeguards, but whether a zoning law and the office of the Zoning Administrator should be burdened with the criminal enforcement of as many as 7 distinct and separate regulatory ordinances.

The basic constitutional principle of procedural due process is that "a trial type of hearing is required on adjudicative facts when important issues are at stake, in the absence of sufficient reason for refusing or modifying a trial type of hearing."[11] As we have seen, performance standards, to be effective, must operate both prior to and after construction of plant facilities. Thus, substantial issues as to the ability of industry to comply with the performance standards are raised both in the prebuilding permit and the postbuilding permit stage. Over these issues serious disputes requiring trial type hearings may arise. The simplicity of the use list approach to industrial zoning has minimized the use of trial type hearings in the prebuilding permit stage. The major administrative problems to date have almost uniformly involved the classification of property rather than a dispute as to whether an industry fits within or is excluded by a use list. The elaborate provisions with respect to administration contained in some of the newer performance standard zoning laws are designed primarily to concentrate authority in the Zoning Administrator and to restrict vastly the reviewing power of appellate boards and courts. With respect to enforcement in the postbuilding permit stage, the ordinances are virtually silent except only as to the provision for fine and imprisonment for failure to comply with these or any other provisions of the ordinance.

This is to be contrasted with a regulatory law such as the new Chicago Air Pollution Control Ordinance which contains administrative provisions, procedures for arrest, and notification of violation; the duty to report discontinuance of the operation; annual inspections, fees, report of equipment failures, and immunity from prosecution during repair period; citation, hearing and sealing of equipment, a separate provision for emergency conditions, and many other provisions, all of which are necessary for the proper enforcement of a regulatory law.

It may well be questioned whether even the most staunch advocates of performance standards in zoning contemplate that the zoning law will be used as the enforcement vehicle indicated above. Yet this is precisely the form of the Chicago ordinance and every other performance standard ordinance written today. In this connection, it cannot be overemphasized that it is one thing to design a piece of equipment to meet a given standard and it is quite another to so operate that equipment as to meet that standard at any and all times. Ordinary wear and tear, human failures in operation, and many other factors make it virtually impossible to have equipment perform according to design from the moment of installation until the day that it is replaced. Yet this is the requirement placed upon that equipment by the performance standards. It appears to this writer that the wisdom of imposing such requirements through the vehicle of a zoning law, ill-designed to provide sufficient enforcement of this type of regulation, is open to serious doubt from an administrative or procedural standpoint.

Conclusion

The theory and purpose of the use of performance standards in zoning is laudable. At the present stage, however, of our scientific knowledge of the fields encompassed by these standards it seems questionable whether performance standards are in fact an improvement over the more conventional use list with respect to the initial placement of industry in an appropriate zoning classification. Proper initial placement is dependent upon our ability to make accurate predictions of conditions yet to be established. The many variables involved in making such predictions caused the author of one standard to admit that his predictions were subject to a margin of error of a plus or minus 20%. The industry which makes large capital investments in a plant in reliance upon such predictions or, what is worse, the acceptance by the Zoning Administrator of a certification of compliance from one not technically trained in the several fields, is in for a rude awakening when it discovers that for one reason or another it cannot either scientifically or economically meet one or more of the standards. The reasonable possibility of this situation occurring raises serious problems of substantive due process.

The problem of the proper enforcement of a technical ordinance of this type is massive. Before performance standards are enforced in a zoning law it should be determined whether the benefit to the community will justify the cost of administration. Certainly very well trained and costly personnel are required to administer these provisions, if they can be administered at all. With ill-trained or poorly paid personnel the possibility of administration abuse is unquestionably present.

Prior to its commitment of capital in a new area industry looks to the zoning law for certainty and assurance of its ability to locate in the proposed site. The one strong point of use list industrial zoning is that it provides that certainty which is required. The performance standard approach fails utterly in this regard. Its prime objective, to prevent the deterioration of industrial uses, can as well be met by properly devised and administered regulatory ordinances on the several subjects covered by the performance standards. Thus, when the constitutional issues raised by substantive due process are satisfied, if science cannot satisfy them today, the combination of use list zoning and nuisance type regulatory ordinances both honestly and vigorously enforced should adequately provide the legal vehicle to achieve tomorrow the goals of today.

REFERENCES

1. Babcock, The Illinois Supreme Court and Zoning, 15 U. Chi. L. Rev. 87

(*Continued on page 174*)

* The new comprehensive Chicago Air Pollution Control Ordinance became effective on May 1, 1959.

Design of AFTERBURNERS *for* VARNISH COOKERS*

JOHN L. MILLS, Principal Engineer, **WILLIAM F. HAMMOND**, Senior Engineer, and **ROBERT C. ADRIAN**, Intermediate Engineer, Los Angeles County Air Pollution Control District

Varnish cooking has figured prominently since the 1920's in many investigations into methods of controlling or eliminating air contaminants. The airborne discharge from varnish cookers is particularly difficult to control because it consists of varying mixtures of solid particles, liquid droplets, condensable vapors and volatile vapors. The methods which have been proposed for air pollution control include dispersion by tall stacks, condensation, absorption, adsorption, chemical oxidation, electrical precipitation, combustion, flocculation by high frequency sound and combinations of these methods.[14]

Only two of these possible methods have been widely used—water scrubbing and combustion.[15] Test data have shown that although water scrubbers show relatively high efficiencies on a weight basis,[16] the odor control problem remains unsolved, since some of the most objectionable odors were found to pass through the scrubber. Such odorous materials were not eliminated even by a test condenser which was held at −109°F, the temperature of a mixture of dry ice and acetone. Direct combustion has been found to be very effective, but flashback fires are a potential hazard. The danger of fire can be minimized by the use of a water spray chamber interposed in the ductwork between the varnish cookers and the combustion chamber. In some instances, boiler fireboxes have been used for incineration of the air contaminants. This report is concerned with the design characteristics of direct-fired afterburners which were constructed specifically for the purpose of destroying air contaminants produced during varnish cooking.

Varnish Manufacture

A large proportion of varnishes may be described as consisting essentially of solutions of one or more of the synthetic or natural resins in a mixture of a drying oil and a volatile solvent. Various additives may also be used such as driers and diluents or thinners and even pigments. In the latter instance the product is more properly described as an enamel. Table I shows the most common of the various ingredients which may be used to produce varnishes, together with some of the characteristic air contaminants which may be involved.

Manufacturing processes vary to some degree. In one method, the resin and the drying oil are heated separately and are mixed together as liquids at a predetermined temperature, after which the mixture is cooled. The thinner and drier are blended in after the temperature has been reduced to below the flash point of the thinner. In another method, the resins may be added as granular or powdered solids to the hot drying oil. Thinning takes place later in the same manner as described in the first method.

During all these processes vaporization of various fractions takes place, accompanied at times by mechanical carry-over of liquid droplets or solid particles. These materials make up the air contamination produced by varnish making. Frequently the use of an exhaust fan is necessary to protect the health of the workers. The vented air contaminants may be the causative agents resulting in complaints about odors, eye irritation and property damage to vegetation, structures or automobiles.

Varnish production involves reaction vessels varying in capacities from less than 100 gallons to several thousands of gallons. The largest reaction vessels are usually jacketed or equipped with coils, thermostatic temperature control devices and automatic stirrers. Installations of this type are capable of being operated with a very minimum generation of air contaminants. A significant

Table I—Common Varnish Constituents and Characteristic Air Contaminants

Class	Drying Oils, Film Forming Materials	Resins	Diluents, Thinners	Other Reactants
Ingredients	Safflower Oil Linseed Oil	Natural Shellac, Rosin	Turpentine Petroleum Solvents	Fatty Acids Glycerol
	Tung Oil	Dammar, Copal, Kauri	Coal Tar Solvents	Pentaerythritol
	Soya Oil Oiticica Oil Castor Oil (Dehyd.) Tall Oil Fish Oils	Synthetic Phenolic Alkyd or Glyptal Epoxy Coumarone-Indene Melamine	Alcohols	Phthalic Anhydride Maleic Anhydride Fumaric Acid Styrene Cyclopentadiene
Materials Identified in Air Contaminants	Acrolein Free Fatty Acids Glycerol Sulfur Compounds	Terpene Oils Phenol Formaldehyde Styrene Monomer	Terpenes Hydrocarbons	All reactants may be lost to some degree
Contaminant Class	Odors Irritants Liquid Particles	Solid Particles Liquid Particles Odors Irritants	Odors Organic Vapors	Odors Liquid Particles Solid Particles Irritants

* Presented at the 52nd Annual Meeting of the APCA, June 21–26, 1959, Statler Hotel, Los Angeles, Calif.

Fig. 1.

segment of the industry, however, still uses the open varnish cooking kettle (Fig. 1). Some types of varnish must be cooked under a blanket of an inert gas in order to prevent excessive oxidation and discoloration. Figure 2 shows a modification of the open varnish cooking kettle as is used for "closed kettle" varnish cooking. This paper discusses afterburners for controlling the air contamination from these two types of kettles.

Nature of Air Contaminants To Be Controlled

The design of an exhaust system and afterburner for the air contaminants must take into consideration both the physical and chemical properties of the materials to be burned. The chemical makeup of the materials vented from varnish cookers may be described as a complex mixture. Acrolein is a fundamental product of linseed oil bodying and has received much attention because of its nauseous odor. Selheimer[17] reports that esterification reactions with polyols such as glycerol or pentaerythritol and tall oil result in the evolution of sulfur compounds such as allyl sulfide, butyl mercaptan and thiophene due to trace quantities of sulfur in the reactants. Odors from such materials and from thinners vaporized during varnish making are frequently the subject of complaints. Certain of the materials, such as acrolein, are also capable of causing eye-irritation. Organic materials in general must also be considered suspect of being oxidizable in the air to form materials irritating to the eyes and mucosa. Pentaerythritol, phthalic and maleic anhydride or fumaric acid additions may result in dust entrainment or fuming by sublimation. If these materials are not controlled, visible plumes will result and most of the materials themselves are irritants to the respiratory tract.[11] Figure 3 illustrates the visible discharge encountered during the addition of dry, powdered phthalic anhydride to soya oil which had been heated to a temperature of approximately 430°F.

During the cooking period, which usually ranges from two to 10 hours, peak temperatures reached may vary in different processes from approximately 350 to 650°F. The discharge of air contaminants does not proceed at a uniform rate during the entire process, and not all discharges are visible. During the thinning process, after the bodying has been completed, significant quantities of the thinner or diluent are vaporized as a result of the heat remaining in the bodied oil. Figure 4 shows a manual thinning operation being carried out in an open-type kettle equipped with a hood for collecting the vapors for incineration.

Exhaust Systems for Varnish Cookers

With the variety of air contaminants vented from varnish cookers, it can easily be seen that certain problems will be encountered in designing an exhaust system. Condensing vapors will collect to some extent as a sticky film on the relatively cool hood and duct walls, forming a collection surface for liquid droplets and solid particles. The ductwork will cool off between periods of use, and the inner surfaces can be expected to be heavily coated after a period of time. Provisions will be necessary to permit regular cleaning of the hoods and the ductwork. Since scrubbers were found to be capable of removing a large part of the particular air contaminants, and since flashback fires are an ever-present hazard, the use of a spray chamber as a duel-purpose auxiliary is recommended. To reduce the maintenance work in cleaning, the exhaust fan should be located downstream from the spray chamber. If provisions are made for protecting the fan from excessively high temperature, it may be located beyond the discharge from the afterburner. Factors affecting the choice of fan location will differ according to sizes of installations, labor costs for cleaning and preferences of the particular managements which are involved. The size, shape and other characteristics of the afterburner itself will be taken up later. Figure 5 shows schematically the essential features of a typical exhaust system and afterburner.

Hooding

Capture of vapors and aerosols from the cookers is as important as the design and construction of the afterburner. A number of types of hoods may be used depending upon the design of the cooker. The requisite features of a hood design include (1) capability for essentially complete capture of air contaminants, (2) provision for access to the kettle during use of the hood, (3) fea-

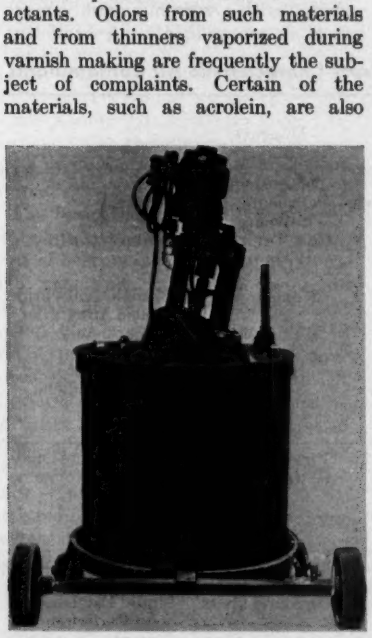


Fig. 2.

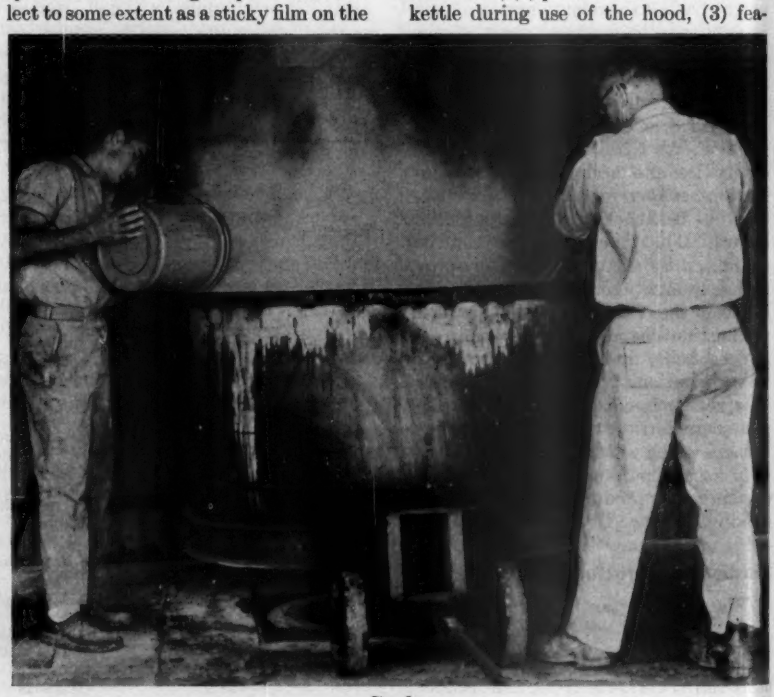


Fig. 3.

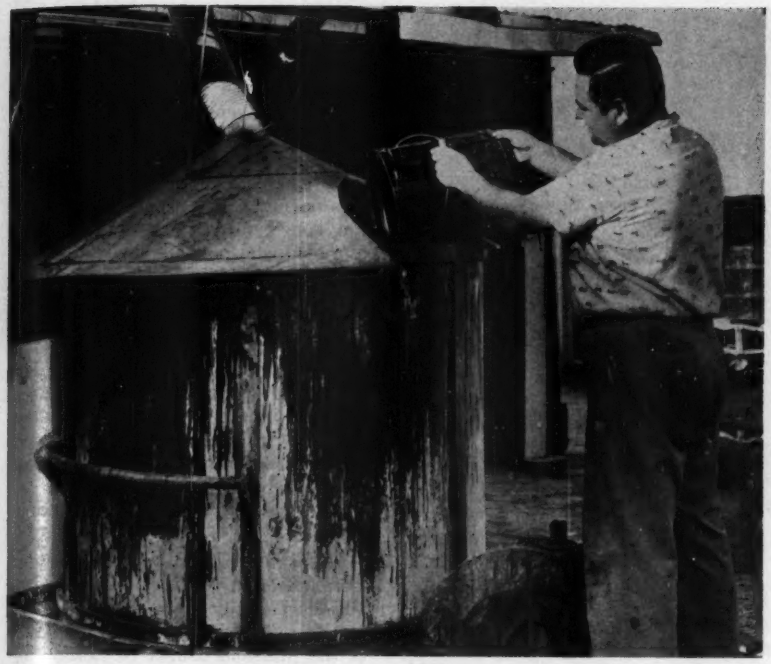


Fig. 4.

tures designed to prevent product contamination by the dripping of condensate from the inner surfaces of the hood, (4) durability, (5) corrosion resistance and (6) ease of handling and cleaning. Figure 6 shows retractable hoods used for portable cookers. These hoods are equipped with access openings for the addition of materials and for thermometers and stirring devices. The hoods are designed so that the condensate is collected in the outer trough, which drains to a container. It has been found by experience that an indraft velocity of approximately 150 fpm must be maintained through the hood openings to assure adequate collection of the air contaminants. A tight hood is, therefore, an economical adjunct to low cost air pollution control, since the amount of air to be heated in the afterburner can thus be minimized.

Ductwork

The major problems in ductwork are corrosion and fouling. One problem which exists adjacent to the kettle hood is that of contamination of the product by the dripping of condensate from the duct. This problem can be overcome by keeping vertical ductwork above the hood at a minimum or by designing the duct with a condensate trap. The total length of ductwork should be kept to a minimum to prevent condensation and accumulation of combustible matter. It is desirable to install ducts with a slope to permit drainage of liquids to traps or drains. With installations where alkyd resins are processed, it is desirable to provide additional features to facilitate cleaning, such as building rectangular ducts, with the top, bottom or one side either removable or hinged. Since some of the chemicals in the air contaminants are corrosive, stainless steel is recommended for ductwork construction. Conveying velocities of 1500 to 2000 fpm have been found to be satisfactory.[6]

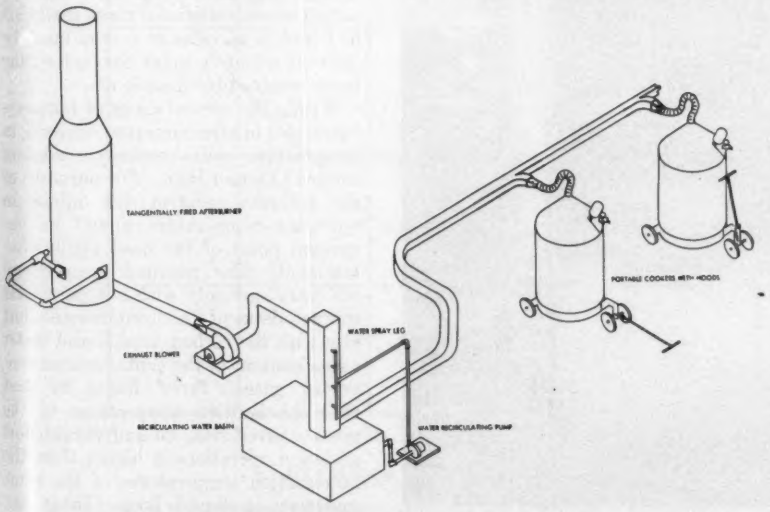


Fig. 5. Schematic plan for varnish cooker control installation.

Precleaning and Flashback Protection

Flashback protection is included with precleaning because most precleaners offer some measure of protection against flashbacks. The most commonly used type of precleaner is the water spray leg, which can remove as much as 88 percent of the weight of the condensable material.[18] In such a device the contaminated gas stream is cooled to provide some condensation of vapors and to permit the removal of the larger particles of mists and solids by the water sprays. A water spray leg may be installed near the kettle to keep the duct cleaning problem at a minimum, or it may be installed near the afterburner to provide maximum flashback protection. Within the limits of fire safety, thus, it follows that the distance between the afterburner and the kettles should be kept to a minimum.

For safety it is preferable in any event to install a section of duct with reduced cross-sectional area immediately preceding the afterburner, in order that a high conveying velocity may be reached. A velocity of about 50 fps is desirable although 18 to 20 fps is reported as being adequate.[3] Since the rate of flame propagation for most of the vapors encountered is less than 20 fps, the flame could not burn back into the duct as long as the high velocity is maintained. As a further refinement, a water cooling jacket may be installed around the duct at the afterburner inlet to prevent heat flow along the duct by conduction. There will be some carbonization deposits encountered in the duct at or near the entrance to the afterburner regardless of design refinements, and periodic cleaning will be necessary.

Afterburner Design Criteria

In designing an incinerator to control emissions where the ratio of the noncombustible gas to combustibles is relatively large and where part of the combustible material is in a widely dispersed particulate state, special consideration should be given to five interrelated variables: reaction temperature, particle sizes of combustibles, mixing, flame contact and residence time. The relationships are essentially empirical because of the range of ma-

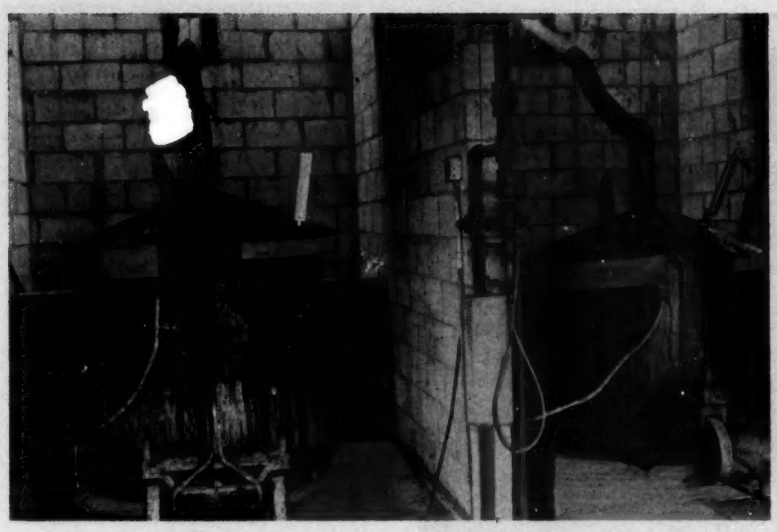


Fig. 6.

terials dealt with and the relatively loose control of operating conditions. As a guide, some use may be made of theoretical data and combustion characteristics of pure compounds. With the advent of rockets and turbojet engines interest has been rekindled in the field of basic combustion research, with the result that explanations can now be given for many observed effects of the above variables. The more subtle factors such as pressure, vibration, synergy and the like are not normally significant in the design of afterburners for varnish cookers.

Combustion Reactions

The intended reaction to dispose of the varnish kettle emissions is oxidation only, with ultimate products of water and carbon dioxide. As oxidation of varnish ingredients occurs even at ambient temperatures, it is apparent that various intermediate reaction products will be formed at some stage of incineration and that the emissions from a poorly designed afterburner may very well include these intermediates. In explanation of smoke formation in combustion it has been proposed that the combustibles are partially stripped of hydrogen in the flame, forming unsaturated compounds.[12] These may then be polymerized, and, as further removal of hydrogen ensues, may result in carbon chains,[13] which appear as soot. Another theory suggests that thermal cracking of the unsaturated compounds may occur either preceding or following the initial stages of oxidation. Regardless of the mechanism, it is clear that aldehydes, acids, peroxides and alcohols are among the initial reaction products.[21] The sensible effect of venting these chemicals to the atmosphere in appreciable concentrations is more objectionable than that of the unburned organic materials. Complete combustion is necessary to prevent the release of these irritating materials.

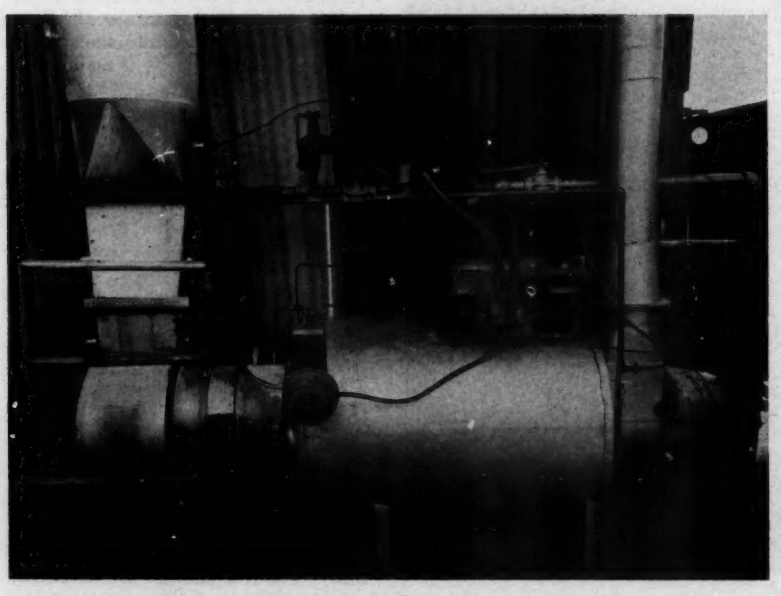


Fig. 7.

The presence of acrolein in the initial emissions from linseed oil bodying may be of some advantage in promoting further combustion. Bawn[1] has shown that under some conditions formaldehyde, acetaldehyde and acrolein accelerate the initiation of the oxidation process. In these circumstances more efficient combustion may be achieved with a given afterburner.

Reaction Temperature

It has been shown by Selheimer and Borchers[16] that varnish kettle emissions vary chemically over a wide range, and therefore the combustion properties of the emissions cannot be closely predicted. A similar wide range appears in the spontaneous ignition temperatures of some of the common materials used in varnishes (Table II). The importance of these variables is, apparent, since several theories of flame propagation propose that a flame is maintained by continuous autoignition at the flame front.[7]

The autoignition temperatures reported for these materials differ according to the method of measurement and can therefore be used only in a qualitative manner. The catalytic effects of surfaces upon ignition temperatures are minimized by the methods used to obtain autoignition temperatures, although these effects may be great under actual combustion conditions. Another consideration that cannot be neglected is the fact that the actual concentrations of these materials as found in an exhaust system must be maintained at a point far below the lower combustible limit in air.

Within the normal range of temperatures used in afterburners an increase in temperature will promote oxidation toward CO_2 and H_2O. For purposes of air pollution control the minimum operating temperature should be the ignition point of the most stable contaminant. The required temperature will vary not only with the particular characteristic of the contaminant but also with the carbon dioxide and water vapor content of the contaminated conveying gases. Jares[8] found by test that the ignition temperature of the mists evolved from oil and varnish formulation operations is higher than the autoignition temperatures of the same materials in liquid form (Table II). As a general rule an average gas tem-

Table II—Ignition Temperatures of Selected Materials Used in Varnishes

Material	Autoignition Temperature,[10] °F	Ignition Temperature of Mist,[8] °F
Stoddard Solvent	444	—
V M & P Naphtha	450	—
Mineral Spirits	475	—
Linseed Oil	820	1150
Castor Oil	840	—
Tung Oil	855	—
Maleic Anhydride	890	—
Toluene	1026	—
Phthalic Anhydride	1083	—
Refined Linseed Oil	—	1130
Linseed and Fish Oil (50-50 mixture)	—	1140
Z-3 Linseed and Z-3 Castor Oil	—	1120
Alkyd, Tall, Pentaerythritol	—	1280
Varnish	—	980–1160
Phenol	1319	—

perature of 1200°F in the incinerator is adequate for burning most of the materials evolved in a varnish cooking or an oil bodying process.

An experiment was performed on an afterburner to determine the relationship between the operating temperature, the visible stack emissions and the efficiency of combustion. Two varnish kettles had been equipped with hoods and an exhaust system, which vented into a gas-fired afterburner similar to that shown in Fig. 7. Spar varnish was maintained at a temperature of 585°F in both kettles.

The operating temperature in the afterburner was varied from 1040°F downward to 750°F, at which point the typical varnish cooker mist appeared at the afterburner stack. The efficiency of combustion at various temperatures was checked by measuring the combustible material content of the afterburner vent gases by a combustible gas indicator. As shown by Fig. 8, the combustible gases vented from the afterburner would not be eliminated until an operating temperature is reached in the vicinity of 1200°F. These data support Jares' findings.

Although temperatures of about 1200°F are usually acceptable, it is recommended that afterburners be designed with a 1400°F capability to provide a margin of safety and to anticipate future changes in process materials. Unusual solvents, e.g., high boiling ketones, and solid particulates may require higher temperatures to insure complete combustion.

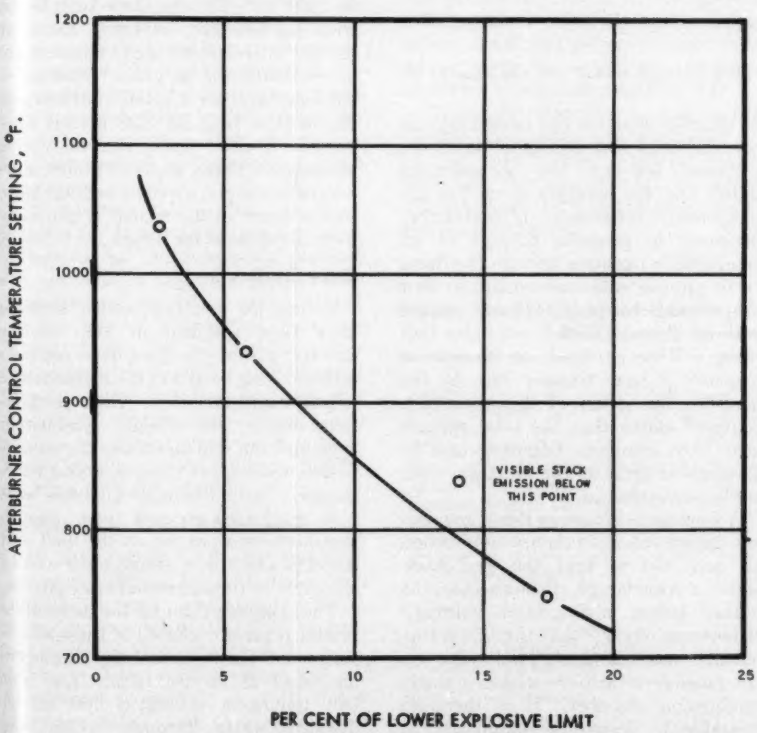


Fig. 8. Variation in combustible air contaminant concentration with afterburner operating temperature during spar varnish cook.

Particle Size

The effect of the size distribution of combustible particles making up a relatively small portion of a mixture of gaseous and particulate combustibles has not been thoroughly investigated. It is normally expected that a reduction of particle size provides an increased surface with correspondingly greater heat transfer rate from the flame to the particle prior to its ignition. Recent data indicate that where the particles alone make up the combustible matter, an optimum particle size of about 60 microns exists for conditions of diffusion flames.[2] Other than precleaners and condensers, no means of particle size control have been used in varnish cooking installations.

Microscopic examinations of particles deposited upon glass slides held above the surface of the hot liquids in varnish cooking kettles disclosed a particle size range of from 2 to 20 microns. The most frequently occurring particles were 8 to 10 microns in diameter.

Although a large percentage of the weight of varnish cooker mists can be removed by a scrubber, the efficiency of such a unit is very low for extremely small particles. Since reduction of visibility is most greatly affected by small particles, the afterburner is necessary to complete the elimination of the air contaminants.

Mixing

An important part of the design of an afterburner is that of assuring mixing within the burning zone. This should be accomplished in the method of introduction of the contaminated gas stream and the burning fuel. Satisfactory mixing can be effected if tangential entries are used in a cylindrical combustion chamber. Both streams may be introduced tangentially as shown in Fig. 9, or one may be injected tangentially and the other along the axis of the chamber. The contaminated gas stream should not be introduced axially, since proper mixing then would require the use of a distributing plate or deflection device at the entrance. Such a distributing plate will become fouled by the impingement of liquid droplets. Accumulations of combustibles near the entrance to an afterburner have been found to cause flashback fires in ductwork.

Since turbulence increases with velocity, adequate gas velocities are essential in the combustion chamber. Average gas velocities are calculated at combustion chamber temperatures for the sum of the volumes of the contaminated gas stream and the products of

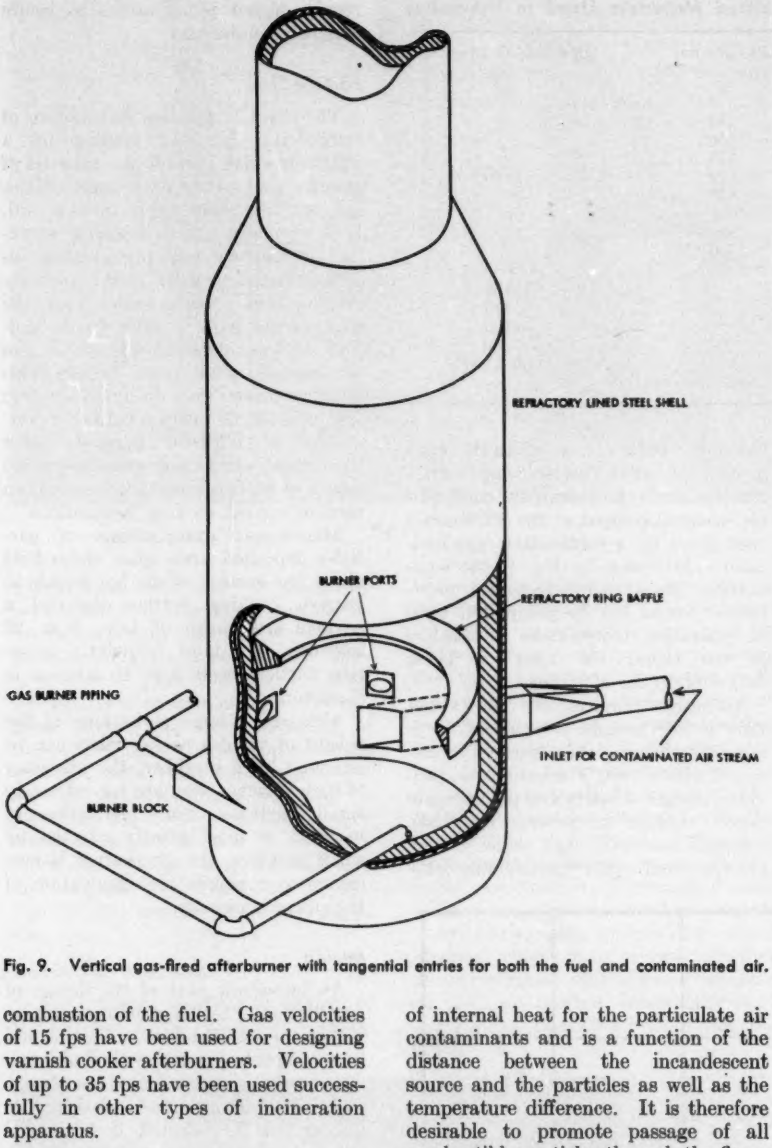


Fig. 9. Vertical gas-fired afterburner with tangential entries for both the fuel and contaminated air.

combustion of the fuel. Gas velocities of 15 fps have been used for designing varnish cooker afterburners. Velocities of up to 35 fps have been used successfully in other types of incineration apparatus.

Flame Contact

Probably the most important design feature of an afterburner is the flame contact with the materials being incinerated. To attain the maximum heating effect of the fuel, intimate contact must be acquired between the combustible material and the flames from the fuel. This requirement becomes apparent when it is realized that the materials to be burned are widely dispersed in an insulating, noncombustible gas stream. The ignition temperature must be reached in a relatively short period of time, and all the methods of heat transfer should be employed if they are available or can be made available. Although the heating of air by radiation is negligible and the heating of combustible gases by radiation is not significantly greater, heat transfer by radiation is the main source of internal heat for the particulate air contaminants and is a function of the distance between the incandescent source and the particles as well as the temperature difference. It is therefore desirable to promote passage of all combustible particles through the flame or to provide sufficient mixing so that all particles will be in intimate contact with the flame. Hottel[4] estimates that there will be as much as 20 percent increase in heat transfer rate to the particles by virtue of flame contact. Topper[20] states that the total radiant heat from luminous flames is four to 21 times as great as the radiation from nonluminous flames.

Achieving a luminous flame requires low mixing rates of primary combustion air and fuel so that the two fluids travel a considerable distance from the burner before mixing and burning.[9] It becomes obvious that maximum turbulence and maximum luminosity are not possible to achieve within a single combustion chamber. It is therefore desirable to design for luminosity in the flame zone combined with as much intimate mixing as can be achieved.

A gas burner with a long, luminous flame will help prevent hot and cold spots from developing within the combustion chamber. Such a burner can fill the combustion space with flames of approximately equal temperatures and result in uniform heating of the refractory lining. Heat reradiated from the refractories provides an additional medium for bringing the combustible particles to ignition temperature.

The completion of combustion under luminous-flame conditions requires more than normal amounts of secondary combustion air because the primary air has been limited deliberately. This situation affords an opportunity for economy in accomplishing air pollution control by the use of the contaminated air stream as the source of secondary air.

Residence Time

The total of induction (mixing or preheat) time and combustion time comprises the overall residence time in the afterburner. Since this figure established the size of the afterburner, it is of major economic importance. Residence time also affects the combustion efficiency.

For organic materials such as paraffin wax, Bunker C fuel oil and other paraffinic and aromatic hydrocarbons, under specified laboratory conditions, it has been determined that the residence time required for high combustion efficiency varies from 0.1 to 0.7 second at temperatures in the range of 1500°F to 1800°F.[5] The residence time varies with particle size, oxidizing character of the atmosphere and temperature of exposure for a given combustion efficiency and for a given hydrocarbon. As short a time as 0.25 second may provide a clear stack, i.e., no visible emissions. Under such conditions, however, efficiency on a weight basis declines, so the figure of 0.5 second is generally more acceptable for design.

Case Studies

Several air pollution control systems have been installed in Los Angeles County within the past few years to serve cooking kettles in the manufacture of paints and varnishes. Some installations employ the straight combustion type and the remainder use the combination water spray condenser and afterburner. Stack discharge analyses have been conducted on each type. Simultaneous tests were run at the inlet and outlet in order to determine the overall efficiency of the individual afterburners.

The sampling train for the particulate matter portion consisted of three series-connected Smith-Greenberg impingers immersed in an ice bath. The first two impingers contained 100 ml of distilled water through which the sampled gases were bubbled. The third impinger was dry with a thermom-

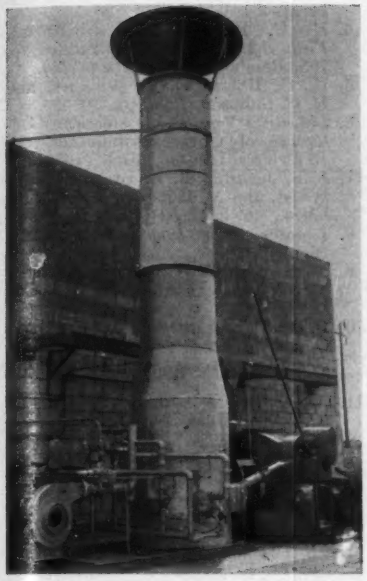


Fig. 10.

eter enclosed and was followed by a Whatman thimble. A Sprague dry gas meter followed the thimble and was equipped with a mercury manometer and thermometer. The gases were then vented through a vacuum pump with a regulating valve. The sampling rates were adjusted to produce isokinetic conditions at the sample probe.

The gain in volume of water in the impingers and the saturation water vapor pressure at the impinger temperature were used for calculation of the moisture content and total volumes of gas samples. It was assumed that the gas passing from the dry impinger was saturated with water vapor at the indicated temperature. This assumption has been verified by long-accepted test procedures.

At intervals during the test, four samples for hydrocarbon analysis were withdrawn at both sampling stations into evacuated two-liter glass bulbs. The collected samples were analyzed by the use of a modified Beckman Model 2 infrared spectrophotometer and reported as hexane. An integrated sample of gas for Orsat analysis was withdrawn continuously from each station by displacement of a concentrated sodium sulfate solution slightly acidified with sulfuric acid.

Tangentially Fired Afterburner

An afterburner of the general type shown in Fig. 10 was tested. This afterburner was constructed with a refractory-lined steel shell with tangential entries as shown in Fig. 9.

The cooking vessels served by the afterburner consisted of two closed reaction kettles and one open kettle with a canopy hood. The reaction products and conveying air were drawn through a water spray leg and an impingement type moisture droplet eliminator section by means of a $1^1/_2$ hp blower. Water was recirculated from the collection tank at the base of the spray leg at a rate of 10 gpm. An overflow trough was installed to allow the collected material in the tank to be skimmed off. A drain at the bottom of the tank was also provided to allow periodic flushing.

The blower delivered the gases to the vertical afterburner through a high velocity section of metal duct. The design velocity through this section was 80 fps. The gases entered at a tangent to the circular afterburner at its base. Above the plane of the burner entry, four nozzle-mix type gas burners were installed, each in a succedingly higher plane and spaced around one-half of the circumference. The burners were horizontally mounted and the firing was directed to enhance circular motion through the combustion chamber. Primary combustion air was supplied to the burners at 8 oz pressure by a single blower. Natural gas was delivered at 1.0 psig to the burners.

The burner control system consists of a Wheelco Capacitrol and motor unit with suitable linkages to both the gas and air lines. The Capacitrol monitored the temperature of the afterburner at a point in the stack near the exit of the combustion chamber by means of a chromel-alumel thermocouple. A high-low mode of control was employed. Safety devices included a flame-failure shut-off unit, electrical failure cutoff and pressure-failure shut-off devices in the air and fuel pipes and in the air contaminant exhaust duct.

During the test of this unit, an oil-modified alkyd resin was being processed in two closed-type reaction kettles equipped for maintaining a carbon dioxide atmosphere continuously above the liquid contents.

There was no visible discharge of air contaminants from the afterburner stack at any time. Capture of mists from the kettles was complete. Air pollution control efficiency was 94 percent with reference to particulate matter and over 99 percent with reference to gaseous organic matter calculated as hexane. A summary of test results appears in Table III, Unit A.

This unit cost $6500 when it was installed in 1956. Fuel requirements are 1,980,000 Btu/hr, the cost of which amounts to about $0.90/hr to incinerate 950 scfm of contaminated air. There are three electric motors for this installation—a $1^1/_2$ hp exhaust system blower, a 2 hp combustion air blower and a $1^1/_2$ hp water pump.

References in the literature have stated that increased afterburner operating costs may be expected where spray chambers are used, as a result of the decrease in the temperature and the saturation of the gas stream with water vapor. During this test an interesting fact was uncovered in regard to the amount of water vapor increase due to the spray leg. Although saturation of the gases passing from the spray chamber was assumed, the moisture content increased only 0.7 percent. The temperature of the contaminated air stream entering the afterburner was 80°F. The temperature drop across the spray leg was 26°F. In these temperature ranges humidity considerations are of minor significance to incineration costs. In this instance the use of the spray leg was calculated to increase the natural gas consumption by the afterburner by approximately 10 ft^3/hr. The additional operating cost would be approximately one-half cent per hour.

Axially-Fired Afterburner

The afterburner unit tested was similar to that shown in Fig. 7 and was

Table III—Summary of Results of Stack Discharge Tests of Two Types of Afterburners Serving Varnish Cooking Kettles

	Unit A	Unit B
Firing Method	Tangential	Axial
Air Entry	Tangential	Tangential
Mixing Method	Orifice	Baffle
No. Kettles Exhausted During Test	2	2
Material Processed	Alkyd Spar Varnish	Linseed Oil
Exhaust System Volume, scfm	950	320
Gas Fuel Use, cfm Fuel Per cfm Exhaust Air	0.032	0.027
Combustion Chamber		
Average velocity, fps	15	12
Length to diam ratio	4	2
Mixing velocity, fps	29	17.5
Average temperature, °F	1220	1100
Residence time, sec	0.7	0.3
Efficiency of Removal, %		
Particulate matter	94	88
Organic acids	50	No data
Hydrocarbons	99+	96

constructed of steel, with a refractory lining. A single venturi-type natural gas burner fires axially into the end of the combustion chamber adjacent to the entry of the contaminated gases. The burner control system consists of a throttling gas controller activated by a temperature sensing device located in the stack near the discharge of the induced draft fan. Safety features include a flame failure fuel shut-off unit, a high temperature limit control and an audible blower failure alarm.

The equipment served consists of three cooking stations and a thinning station. At the thinning station the batch of processed oil is cooled and diluted with a thinner such as mineral spirits, toluene, etc. The canopy hood collection system ventilates all four stations and conducts the exhaust air to the afterburner. This installation was not equipped with a water spray leg.

During the test of this afterburner, two of the cooking stations were in use processing linseed oil. There were no visible air contaminants in the discharge stack from the afterburner. With the temperature in the afterburner averaging 1100°F, the efficiency of removal of particulate matter was 88 percent. The gaseous samples for hydrocarbon analysis indicated an efficiency of 96 percent by the modified Beckman Model 2 infrared spectrophotometer. Details of the results of the test appear in Table III, Unit B.

The afterburner cost $2500 installed. Fuel requirements are 570,000 Btu hr, the cost of which was about $0.26 hr. One 2 hp electric motor is used in this installation.

Odor reduction capability of a similar axially-fired afterburner unit was investigated. Two cooking stations were in use processing castor bean oil in one and linseed oil in the other. When the oil in the kettles reached a temperature of 565°F, odor determination was begun. Strong, suffocating odors were released from the afterburner stack with temperatures in the combustion chamber at 1000°F and lower. At a setting of 1060°F, however, only traces of odors could be detected. This observation shows that such odors can be eliminated by incineration methods. It has been shown that odors cannot be adequately removed by water scrubbing.[19]

Summary and Conclusions

The air pollution problems from oil bodying and varnish cooking in batch type vessels can be adequately and economically solved by direct incineration of the combined particulate and gaseous pollutants.

Since individual installations may involve different numbers of cookers as well as various types of varnishes, no single design can be applied universally. In designing a control system, the following items should be considered:

1. Hooding. Hoods should be tight-fitting to assure adequate mist capture with minimum air flow consistent with protection against explosion hazard. Ease of cleaning is a critical consideration because of the danger of batch spoilage from dripping condensate.

2. Ductwork. Ducts should be sloped away from the hoods and low spots should be eliminated or provided with drainage. Ducts should be designed for facility of cleaning. Corrosion resistant ducting materials should be used.

3. Flashback Protection and Precleaning. A water spray leg is recommended for precleaning and flashback protection. A high velocity section at the afterburner inlet provides additional fire protection.

4. Afterburner. The afterburner should be designed for a minimum gas temperature of 1200°F with a capability of being operated at 1400°F and should provide for intimate mixing of the contaminated gas stream with a luminous flame. The combustion chamber should be refractory-lined and should provide for a residence time of 0.5 second. The velocity of the gases through the chamber should not be less than 15 fps.

5. Controls. Burner controls should be of the modulating type to insure continuous and uninterrupted flame coverage in the combustion chamber. Shielded thermocouples should be employed and should be installed near the vent from the combustion chamber in order that the gas temperature but not the flame temperature will be measured.

6. Safety. Since fires are great hazards in varnish plants, protection must be provided for all possible types of failures in the air pollutant exhaust and control system.

This study has resulted in determining some of the desirable design features for afterburners for varnish cooking kettles. Further study is needed to produce an optimum set of standards. It is believed that a length to diameter ratio of 5 to 1 will produce even better results. It is also believed that a baffle inserted near the exit end of the combustion chamber will aid in completing the combustion by inducing turbulence after the effect of intimate flame contact has subsided.

REFERENCES

1. C. E. H. Bawn and G. Skirrow, *Fifth Symposium on Combustion*, pp. 521–29, Reinhold, New York (1955).
2. J. A. Browning, T. L. Tyler, and W. G. Krall, *Ind. & Eng. Chem.*, **49**, 142–7 (1957).
3. A. G. Christie, *Ind. & Power* (December, 1948).
4. H. C. Hottel (Panel Chairman), *Fifth Symposium on Combustion*, p. 795, Reinhold, New York (1955).
5. H. C. Hottel, G. C. Williams, and H. C. Simpson, *Ibid.*, pp. 101–29.
6. *Industrial Ventilation*, American Conference of Governmental Industrial Hygienists, Lansing, Mich. (1956).
7. J. L. Jackson, R. S. Brokaw, R. C. Weast, and M. Gerstein, *Ind. & Eng. Chem.*, **46**, 2547–50 (1954).
8. J. Jares, *Chem. Engrg.*, **56** (January, 1949).
9. *North American Combustion Handbook*, The North American Mfg. Co., (1952).
10. *Properties of Flammable Liquids, Gases & Solids*, The Factory Mutual Engineering Division, Bulletin 36.10 (1954).
11. N. I. Sax, *Dangerous Properties of Industrial Materials*, Reinhold, New York (1957).
12. R. L. Schalla, G. E. McDonald, National Advisory Committee for Aeronautics, Research Memorandum E52I22 (1952).
13. R. L. Schalla and G. E. McDonald, *Fifth Symposium on Combustion*, pp. 316–24, Reinhold, New York (1955).
14. C. W. Selheimer, T. J. Daly, *Official Digest of Federation of Paint and Varnish Production Clubs*, **27**, 769–72 (1954).
15. C. W. Selheimer and H. Bauman, *Ibid.*, **27**, 574–94 (1954).
16. C. W. Selheimer and C. H. Borchers, *Ibid.*, **27**, 684–710 (1954).
17. C. W. Selheimer, J. P. Antolak, and J. Paskind, *Ibid.*, **27**, 647–52 (1954).
18. C. W. Selheimer and C. H. Borchers, *Op. Cit.*, p. 694.
19. *Ibid.*, p. 706.
20. L. Topper, *Ind. & Eng. Chem.*, **46**, 2551–58 (1954).
21. G. Von Elbe, *Fifth Symposium on Combustion*, pp. 79–85, Reinhold, New York (1955).

Health Congress Coming July 25-29

The 13th International Congress on Occupational Health will be held July 25–29 at the Waldorf-Astoria in New York City. APCA's President Dr. Leonard Greenburg is a member of the Executive Committee in charge of the meeting.

Held every three years under the auspices of the Permanent Committee and International Association on Occupational Health, the Congress will draw participants from all over the world. Major sessions will be Work Physiology and Psychology, Administrative Practices, Education and Training, Influence of Environmental Factors—Pneumoconiosis, Medical Practices, Influence of Environmental Factors—Radiation, and Social and Legal Aspects.

Persons desiring to present a paper should contact the Program Chairman Dr. Irving R. Tabershaw, 375 Park Avenue, New York City. Additional information concerning the program can be obtained by writing the Organizing Committee, Dr. Leo Wade, 15 West 51st Street, New York City.

Informative Report

By APCA TI-2 Chemical Committee

Foreword

The Chemical Industry's Air Pollution Problem

The Chemical industry uses raw materials from mine, forest, sea, air, farm, and from oil, brine, and gas wells. It converts these widely diversified raw materials into more than 8850 compounds, called "end chemicals," in more than 12,000 plants operated by hundreds of chemical manufacturers.[1]

Governmental agencies have established a category known as "Chemicals and Allied Products."[2] (See Appendix for this listing.)

Since World War II, the chemical industry has become so diversified that it is difficult even to classify it accurately. Today, petroleum producers are important chemical manufacturers; paper companies, rubber companies, even manufacturers of electrical machinery and farm equipment are chemical producers.

An outstanding characteristic of the chemical industry is strenuous competition among companies. Competition goes on in several ways:

1 Competition between products for similar markets: Glycerin, sorbitol, propylene and ethylene glycols, ethanol, methanol, isopropyl alcohol, and pentaerythritol perform many of the same functions.
2 Competition between processes: Acetic acid is made from three different raw materials by 10 different processes. Ethylene glycol, widely used as an antifreeze, is made by three different processes. Phenol is also synthetized by three different processes.
3 Competition between raw materials: Petroleum is competitive with natural fats for detergents, coal is competitive with petroleum as a source of phthalic anhydride, petroleum is competitive with molasses for ethyl alcohol production.

Here are the number of chemical manufacturers competing with each other in certain fields: plastic material manufacturers, 110; sulfuric acid, 80; photo chemicals, 12; explosives, 19; dyes, 52; organic intermediates, 137; paints, 1500; synthetic ammonia, 28; and oxygen, 109.[1]

All this has made especially appropriate to the chemical industry the following statement from the "Air Pollution Handbook."[3]

> "Over a period of years it has been found that certain types of processes have been successfully adapted to certain situations, and the experienced users have indicated preferences. Where this has occurred, an effort has been made to point out the reasons for the choice. Because of the wide variations of conditions that are encountered in practice, it is only rarely that direct transfer of equipment or processes can be made from one installation to the next. Thus each case should be considered individually and the controlling factor in each carefully weighed."

The TI-2 Committee has taken note of the foregoing facts concerning the chemical industry. These facts quite clearly indicate that finding satisfactory answers to the nine items listed as requirements for Technical Council approval do not form a practicable basis for air pollution control for the chemical industry.

The TI-2 Committee, after careful consideration as explained above, submits the following Program Outline as the best method now available for dealing with the air pollution problems of the chemical industry. If acceptable to the Technical Council, and if subsequently approved by the Board of Directors, the Committee will undertake the continuing task of adding paragraphs on control methods and equipment for specific chemical processes as the information is made available.

Program Outline

I The air pollution control official has one major concern with respect to an industrial plant. This concern is: "Is or will *this* plant be a nuisance in *this* location?"

Almost every chemical plant is a unique problem in respect to air pollution. Rarely are two plants built the same way, even though the same basic process is used. The newer plant will have built into it improvements which were learned from operation of the older plant, and as a result, the waste products may be different in type and amount. The location of the plant is obviously of major importance.

Air Pollution abatement from chemical plants is often a highly complicated and technical problem. The duty of the Control Official should be to tell a plant which of its effluents is causing a nuisance and it should be the duty of the plant to reduce that discharge to an acceptable level. Each plant is a separate problem. From each plant it is suggested that the Control Official elicit the answers to the questions listed below:

1 What materials usually considered as air pollutants are discharged in normal operations?
2 Physical state of these materials (gases, dusts, smoke, and fumes).
3 Give available data on the characteristics of these materials (such as range of particle sizes, color, etc.).
4 Which materials are released at (*a*) ground level, (*b*) from roof top, and (*c*) from high stacks?
5 Are these discharges regular or intermittent?
6 Are any of the materials emitted known to create nuisance other than by smell or dirt (e.g., damage vegetation, discolor paint, irritate the eyes or nasal passages, etc.)?
7 Give available data on any reaction of emitted materials after release into the atmosphere.
8 Give available data on any emitted material known to be a significant hazard at ground level concentrations to be expected.

Comments on the Questions

Obviously what and how much are the starting points. Usually, a plant will be able to supply this information. Oc-

casionally, losses from an open tank or ventilation ducts may be overlooked and specific questions along these lines may be in order. Often, it is quite difficult to measure accurately the quantities vented, but it is almost never necessary to know the exact amounts of these wastes. Usually, an error of ±25% in quantities is acceptable.

The physical state of the wastes is important because of the effects they might have. Finely divided solids (dusts, fumes, smokes) reduce visibility, may cause unsightly deposits, and act as irritants. Very seldom will the solids themselves have an odor, but they may be mixed with gases that do smell. Gaseous wastes may have an odor but will not affect visibility unless they condense or react in the atmosphere. Liquids seldom are problems in air pollution except for a few such as fumes of sulfuric acid which may occur from heating sulfuric acid, some sulfates, or sulfur-bearing materials.

The odors of the wastes have a direct bearing on the nuisance potential. Odors are notoriously difficult to describe. Unless the Control Officer is personally familiar with the materials involved, he should try to obtain samples to smell. It should be emphasized that odors of some chemicals change on dilution, and mixtures of materials may smell quite differently from their individual components.

In many cases, it is also helpful to know what concentrations of a particular compound in air is necessary for its odor to be detected. There have been a number of ingenious methods developed to make such measurements.[6] Since individuals vary considerably in their sense of smell, it is advisable to make these tests with as many different observers as possible.

The particle sizes of dust or smokes have very great effects on their behavior. Particles appreciably larger than one micron tend to settle rapidly, often making gritty deposits but seldom travel more than 1/4 mile in the air. Particles smaller than one micron may travel great distances, and clouds or plumes of such particles may be visible for miles from the discharge point. These sizes are in the range of wave lengths or visible light and are most effective in reducing visibility. A small weight of particles of 0.5 micron diameter can produce a large opaque cloud. This size particle is also particularly prone to soil windows. These particles are generally the result of high temperature processes (furnaces, kilns, etc.).

In general, the higher above ground level an effluent is released, the more effectively it will be diluted before it comes back to ground. Several methods have been developed to calculate the effect of stack height on ground level concentration.[5]

In the vast majority of cases, air pollution is a nuisance because of odors or dirt. Occasionally, however, other effects are noted. Hydrogen sulfide, for example, will darken paint which contains white lead. Sulfur dioxide and some other compounds may damage vegetation.[7]

Sometimes an effluent may be clear and satisfactory as released, but in the atmosphere it may react with other compounds to form a haze or irritant. Smog formation is the best known example of this. Traces of ammonia in the air can react with almost any acidic gas such as sulfur dioxide to form a haze.

Regulations or rulings for the purpose of "controlling" pollution in a given region should be arrived at on the basis of the evaluation of conditions and of rates of emission of contaminants. The basis of such regulations or rulings, of necessity, will vary greatly. In the case of SO_2 and damage to vegetation, acceptable or non-injurious levels are well known (for all practical purposes) and non-injurious rates of emission can be determined rather directly. On the other hand, acceptable levels of odorous substances or of dirt, for example, are indefinite, being subjective in nature and the degree of restriction of emissions may have to be determined on other bases than a direct mathematical relationship to the effects.

Intensive studies on the health aspects of air pollution are now being conducted by many investigators. The need for such studies is summed up in the following paragraph from the Air Pollution Handbook:

> "Pollution of the ambient air, at least to some degree, has been universal since the beginning of time and is certain to continue in the future. Although much has been accomplished by various investigators in detecting and measuring air burdens, only scanty and fragmentary evidence is available regarding the possible injurious effect on living organisms following long exposure by inhalation or deposition of small or even trace amounts of the various contaminants emitted by modern industrial processes. Even with severe pollution, when the amount of material discharged can be measured in tons, the atmosphere of an industrial area will contain only trace quantities far below the values customarily accepted as harmful for man. It must be recognized, however, that pollutants will be present in complex mixtures which may have an additive or synergistic effect. However, the subject as a health problem should not be discounted or avoided because it is complex, but rather the possible physiological effects of the various situations and conditions of man, animals, and plants should be intensively studied and properly evaluated. With field and laboratory methods which would permit a careful and critical appraisal of the factors involved in any given situation, it should be possible to justify at least reasonable control, if not total prevention, of harmful atmospheric pollution."[8]

There is no substitute for good judgment in air pollution abatement. The preceding sections should bring out facts which are needed to set up a good program. The Control Officer should consider the potential nuisance from a plant in relation to its neighborhood, other plants in the vicinity, and location in respect to wind dispersion and direction. Then he should decide what is a reasonable amount of air-borne materials for that plant to release.

II Much valuable information is available that can be of assistance to the Air Pollution Control Official in evaluating emissions from chemical processes. One information source, widely known and useful because of its broad coverage of most aspects of air pollution, is the Air Pollution Abatement Manual of the Manufacturing Chemists' Association.[5] In addition to several chapters, each dealing with a specific technical aspect, this manual includes a bibliography listing many other sources of data published through 1954 on air pollution information.

The Air Pollution Handbook,[3] though not considered as an infallible guide, is of value as a most complete reference book on air pollution from many sources.

The literature on the many aspects of air pollution is growing rapidly. Universities, foundations, consulting services, industrial companies, or trade associations, and other agencies including all levels of government are now engaging in the development and research. The outpouring of published papers has become so great that bibliographies of newly published work are now published on a regularly scheduled basis. Such bibliographies are maintained by the Air Pollution Control Association and the Bureau of Mines.

III As indicated in the foreward, if desired, the TI-2 Committee can form time to time supply data on equipment and methods currently used for air pollution control in relatively standardized chemical processes. Since even in these cases the equipment and processes are far from uniform as between different companies or even of different plants of the same companies, it would seem advisable to submit these as supplements to this report as the

information becomes available.

REFERENCES

1. The Chemical Industry Facts Book, Manufacturing Chemists' Association, Inc., Washington, D. C., Third Edition.
2. Standard Industrial Classification Manual, Manufacturing Industries, U. S. Bureau of the Budget, Vol. 1.
3. Air Pollution Handbook, Edited by Paul L. Magill, Francis R. Holden, and Charles Ackley, McGraw-Hill (1956).
4. APCA Committee on Committee Reports, Revised (October 7, 1957).
5. Air Pollution Abatement Manual, Manufacturing Chemists' Association.
6. "The Air Over Louisville," Special Air Pollution Study, PHS Community Air Pollution Program.
   J. Von Bergen, Industrial Odor Control, *J. Air Pol. Control Assoc.*, **8**: 101–111, (Aug., 1958).
   J. F. Mateson, Olfactometry; Its Techniques and Apparatus, *Proc., Air Pol. Control Assoc.* (1955).
7. F. W. Went, Plant Damage Due to Air Pollution and the Use of Plants as Indicators of Air Pollution, *Proc. Air Pol. Control Assoc.* (1957).
8. John J. Phair, The Epidemiology of Air Pollution, Dr. P. H., Professor, Dept. of Preventive Medicine and Industrial Health, University of Cincinnati.
9. Standard Industrial Classification Manual, 1, Manufacturing Industries, U. S. Bureau of the Budget.

Appendix

CHEMICALS AND ALLIED PRODUCTS INCLUDE THE FOLLOWING.[9]

Industrial inorganic chemicals
- Alkalies and chlorine
- Inorganic chemicals, not elsewhere classified, includes sulfuric acid; inorganic acids, such as boric, hydrochloric, nitric, and phosphoric; inorganic salts of sodium, magnesium, potassium, calcium, aluminum, chromium, mercury, nickel, silver, and tin; inorganic compounds such as alums, calcium carbide, sodium silicate, ammonium compounds, and anhydrous ammonia; elemental bromine and iodine

Industrial organic chemicals
- Coal tar crudes
- Synthetic resins and plastics materials
- Synthetic rubber, synthetic fibers
- Explosives
- Organic chemicals, not elsewhere classified—intermediates, dyes, color lakes, toners, organic acids, such as acetic, tartaric, formic, and their metallic salts; solvents; synthetic perfume, and flavoring materials; rubber accelerators and anti-oxidants; plasticizers; synthetic tanning materials; chemical-warfare materials

Soap and related products
- Soap and glycerin
- Cleaning and polishing preparations

Drugs and medicines
- Biological products

(*Continued on page 174*)

New DAY "RJ" Dust Filter

CONTROLS DUST SAVES DOLLARS

only 3 moving parts

Built under patents of The DAY Company and H. J. Hersey, Jr.

Because of its new, simplified design the DAY "RJ" dust filter will save you many dollars on initial investment, installation, operation and maintenance. Some of the important new construction features of this dust filter are: a new, quick-opening reverse-air, counter-flow valve for maintaining filter media porosity; a new, reverse-air pressure blower arrangement, and new, air tight, yet quickly opened inspection doors.

This patented DAY dust filter has only 3 moving parts but controls dust effectively, efficiently (99.99+%) and economically. It represents the latest refinement in a long-tested, plant-proven dust filter. Using felted filter sleeves to capture dust, the "RJ" is now available in 5 sizes for handling from 300 to 6400 CFM of air (for larger capacities, multiple groupings are furnished).

For more detailed information write toDAY for free Bulletin G-30. It's filled with facts, specifications and dimensions.

The DAY Company

SOLD in UNITED STATES by
The DAY SALES Company
862 Third Avenue N.E.
Minneapolis 13, Minnesota
FEderal 6-9671

MADE and SOLD in CANADA by
The DAY Company of Canada Limited
Rexdale (Toronto), Ontario, Canada
Fort William, Ontario, Canada
Rexdale, Cherry 1-8589

Representatives in Principal Cities

EXPERIENCE ENGINEERED . . . LABORATORY TESTED . . . PLANT PROVEN
Dust Control • Pneumatic Conveying • Bulk Storage
EQUIPMENT . . . SYSTEMS . . . INSTALLATION

★ ★ ★ Section Hi-Lights ★ ★ ★

Mid-Atlantic States Section

The Mid-Atlantic States Section annual Technical Conference was held March 29 in Atlantic City. Entitled "Considerations in Solving Industrial Gaseous and Volatile Wastes Problems," the Conference was held in conjunction with a meeting of the N. J. Sewage and Industrial Wastes Association.

The entire Conference on Solving Liquid and Gaseous Industrial Wastes Problems lasted two days at the Hotel Traymore.

Speakers and topics included in the Mid-Atlantic meeting were Dr. Leonard Greenburg, APCA's president, who gave the welcoming address; Austin Heller, Allied Chemical Corp., spoke on "Recognition and Definition of an Industrial Gaseous and Volatile Waste Problem"; and Jerome Wilkenfeld, Hooker Chemical Corp., discussed "Pollution Control by Pollution Avoidance."

The afternoon session featured a panel discussion on "Design, Operation, Control of Specific Gaseous and Volatile Waste Treatment Installations." Speakers were Fred Lorentz, Hoffman-LaRoche, Inc.; Richard Ladd, Tide Water Oil Co.; Stanley Paist, Rohm and Hass Chemical Co.; and Roy Johnson, American Chemical Products, Inc.

Niagara Frontier Section

The Niagara Frontier February 25 meeting featured Warren Rother of the Kellogg Mann Corp. who spoke on "Industrial Incineration." A film by Dow Chemical Co. was also shown. Its title was "New Industrial Incinerators."

The March 31 meeting was held with the New York Sewage and Industrial Wastes Association. The meeting was held in Niagara Falls, N. Y., and featured tours of the three quarter billion dollar Niagara Power Project which is half done, and of the Niagara Sewage Disposal Plant situated in the Niagara River gorge.

The April meeting will be at the Sheraton Brock in Niagara Falls, Ontario. A program featuring the International Nickel Co. is planned.

West Coast Section

The beginning of the current fiscal year of the West Coast Section, February 1, 1960, was marked by three events, a meeting of the Executive Committee, a social hour, and a dinner meeting.

In the Executive Committee meeting, plans were discussed for the coming year with regard to committee appointments, continuation of the dinner meetings which have proved so successful in the past, a one-day technical meeting later in the year, and amendments to the By-laws.

At the dinner meeting at the Long Beach Petroleum Club, the newly elected officers for 1960 were introduced. These are Mr. Gerald Fisher, Chairman, Mr. Dale Hutchison (not present), Vice President, and Mr. Robert Lunche, Secretary-Treasurer. The past Chairman, Mr. John Maga, and members of the Executive Committee, Mr. George Taylor and Dr. W. L. Faith, were also introduced at the meeting.

Following the dinner, a technical program was presented on the co-operative study being conducted by the Western Oil and Gas Association and the Los Angeles County Air Pollution Control District. Presentation was made by a panel of three research chemists intimately concerned with the study.

This study was initiated to resolve the many questions regarding the effect of gasoline composition upon air pollution potential of automobile exhaust gases. These studies were stimulated by passage of Rule 63 and by the APCD contention that the reduction of olefins in gasoline would reduce the smog potential of automobile exhaust emissions. Commenting on recently enacted Rule 63 which limits the olefin content of gasoline sold in Los Angeles County, Dr. Mader stated that although the substitution of one pollutant for another is contrary to true air pollution control principles, it is justified as an interim measure.

From the preliminary studies upon which Rule 63 was predicated, it was concluded by the APCD that the olefin content of automobile exhaust was related to the olefin content of the gasoline burned and the capability of auto-

(*Continued on page 175*)

1959 APF REPORT OFF THE PRESSES

The Air Pollution Foundation *Newsletter* announced recently that the APF Report No. 30, "Sixth Technical Progress Report," is off the press and ready for distribution.

This Report summarizes the work sponsored by the Air Pollution Foundation during 1959 and the studies done by other groups on aspects of air pollution that are pertinent to the Los Angeles smog problem. Additionally, the fourth and concluding chapter, "Air Quality and Motor Vehicle Exhaust Standards," presents a discussion of the anti-smog standards recently adopted by the California State Board of Public Health.

Chapter I, "Photooxidation of Hydrocarbons," is a resume of work conducted as part of our continuing project at Stanford Research Institute, South Pasadena. Chapter II, "Treatment of Motor Vehicle Exhaust Gases," reviews a Foundation-sponsored study of catalytic treatment of exhaust and a project in which they unsuccessfully sought development of foamed metals to deactivate the lead in exhaust, and includes a 15-page discussion of the status of exhaust control devices. Chapter III, "Research in Atmospheric Chemistry," updates the important field of atmospheric chemistry by reviewing the work of various laboratories.

Buell Buys Norblo

Buell Engineering Co., Inc., one of the nation's producers of electrical and mechanical dust collecting equipment, has purchased the 49-year-old Northern Blower Co. (Norblo) of Cleveland, Ohio according to J. A. McBride, president.

Under terms of the acquisition, L. A. Eiben will operate The Northern Blower Division of Buell as a vice president within the framework of the Buell organization. Norblo manufactures bag-type collectors and filtering equipment.

CALENDAR

April 24–28	1960 Industrial Health Conference, Rochester War Memorial Auditorium, April 24–28 (earlier meetings in Hotels), Rochester, New York.
April 25–29	Training Course in "Analysis of Atmospheric Inorganics," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio.
May 2–6	Training Course in "Analysis of Atmospheric Organics," same as above.
May 19–20	Postgraduate course "Effect of Air Pollution and Environment on Health," University of Wisconsin, Madison, Wis.
May 22–26	**53rd APCA Annual Meeting, Netherland-Hilton Hotel, Cincinnati, Ohio.**
July 25–29	13th International Congress on Occupational Health, Waldorf-Astoria Hotel, New York City.

LOS ANGELES APD LOSES CHAMBERS

Dr. Leslie A. Chambers, Director of Research for the Los Angeles Air Pollution Control District, will leave that post to become Scientific Director of the Allan Hancock Foundation at the University of Southern California. His resignation becomes effective April 29.

Air Pollution Control Officer Smith Griswold declared, "I have accepted Dr. Chambers' resignation with deep regret. His work, since coming to the District in 1956, has been a valuable contribution not only here, but to the solution of the problem of air pollution throughout the entire world."

Under Dr. Chambers direction the studies were conducted into fuel composition that led to the adoption of Rule 63 regulating the amount of olefins permitted in gasoline sold in Los Angeles County.

In his letter of resignation, Dr. Chambers pointed out that he came to the District with the understanding that he would leave as the research program matured and emphasis could be shifted away from the area in which he was most interested, that of exploratory research. He said he felt that this development had been achieved.

According to Mr. Griswold, there will be no replacement of Dr. Chambers, until there has been a review and reappraisal of the research program and its objectives.

Benline Appointed

Arthur J. Benline, former Superintendent of the Housing and Buildings Department of New York City, has been appointed by Mayor Robert Wagner to take over the position of Commissioner of Air Pollution Control, recently vacated by APCA's President Leonard Greenburg.

Mr. Benline is a native New Yorker with an engineering degree from New York University. A personal friend of Mayor Wagner, he worked directly under him when the budding politician was named head of the Buildings Department by Former Mayor William O'Dwyer. Mr. Benline left the Buildings Department in 1952.

Mayor Wagner urged Mr. Benline to take the new position and give up his most recent position as Technical Director of the State Building Code Commission.

Ironically, while Mr. Benline was serving in the Naval Construction Battalion as a lieutenant commander, he was responsible for generating a smoke cover over Okinawa to discourage Japanese Kamikaze pilots.

Editor's Note: The article "Eye Irritation from Air Pollution" by Hine, Hogan, McEwen, Meyers, Mettier, and Boyer, which appeared in the Feb., 1960, JOURNAL, contains an error which we were unable to correct before publication. The last paragraph under the heading *Animal Exposure*, just before the section titled *Human Exposure*, found on page 18 begins "On chronic exposure to sulfur dioxide. . . ." This paragraph should read "On chronic exposure, none of the gases produced a positive effect, even though the concentrations of ozone and acrolein were near lethal levels."

NEW MEMBERS

(*Continued from page 155*)

Thomsen, John E.
Tomkins Cove, New York

Tolle, Kendall L.
Lakeland, Florida

Whitcomb, Jr., David
Seattle, Washington

Young, G. H.
Pittsburgh, Pennsylvania

COMPANY MEMBERS

Consumers Union of U. S., Inc.
Mount Vernon, New York

Kawecki Chemical Co.
Boyertown, Pennsylvania

Minerals & Chemicals Corp. of America
Menlo Park, New Jersey

Mississippi Chemical Corp.
Yazoo City, Mississippi

National Gypsum Co.
Buffalo, New York

New York Oil Heating Assn., Inc.
New York, New York

Pennsylvania Electric Company
Johnstown, Pennsylvania

J. P. Stevens & Co., Inc.
New York, New York

Torit Manufacturing Co.
St. Paul, Minnesota

Washburn & Granger, Inc.
Paterson, New Jersey

Wellman-Lord Engineering, Inc.
Lakeland, Florida

Wilco Machine Works, Inc.
Memphis, Tennessee

SUSTAINING MEMBERS

National Coal Association
Washington, D. C.

Riley Stoker Corp.
Worcester, Massachusetts

In Memoriam . . .

Harold L. Anderson passed away in Columbus, Ohio, December 24, 1959. He was one of the original smoke inspectors of the city and had been with the Division of Smoke Regulation and Inspection over ten years. During that time he performed many duties. His last assignment was that of Acting Assistant Division Chief.

New York School Offers Free Series

The Department of Meteorology and Oceanography of New York University announced a series of 13 free, public lectures on Radioactivity in the Atmosphere to be presented by distinguished experts in the field.

Held on successive Tuesdays beginning March 1, the lectures will include the following titles:

1. The Radioactive Environment
2. Monitoring Radioactive Fallout
3. Atmospheric Radioactivity: Studies at the U. S. Naval Research Laboratory, 1948–60
4. The Vertical Distribution of Radioactivity in the Atmosphere
5. Distribution of Man-Made Radioisotopes on the Earth
6. Atmospheric Radiocarbon and Meteorological Processes
7. The Distribution of Bomb-Produced Radioactivity in the Stratosphere
8. Atmospheric Circulation Tracing with Selected Radioisotopes
9. Stratospheric Aerosols
10. Mechanism of Aerosols and Their Behavior in the Stratosphere
11. Applications of Natural Radioactivity to Meteorology
12. Meteorology and the Atomic Energy Industry
13. Applications of Man-Made Radioactivity to Meteorology

For further information contact Prof. Jerome Spar, Department of Meteorology and Oceanography, New York University, New York 53, N. Y.

Water Federation Votes Name Change

Dr. Mark D. Hollis, president of the Federation of Sewage and Industrial Wastes Associations, announced recently that the Federation Board of Control had voted to change the Federation name to WATER POLLUTION CONTROL FEDERATION effective January 1, 1960.

Further announcement was made that the monthly technical Journal of the Federation known as SEWAGE AND INDUSTRIAL WASTES for the last ten years, will assume its new name in January, 1960 as JOURNAL of the WATER POLLUTION CONTROL FEDERATION. Paid circulation of this Journal is well over 10,000 and it reaches all parts of the world. In addition to its member associations in North America, the Federation boasts of five in Europe, one in Israel, and one in New Zealand.

APCA HISTORY

(*Continued from page 137*)

Mines, Washington, D. C. Very active in the Association for years. Has presented many papers, participated in panel discussions and symposia. He is an Honorary Member of the Association.

1923 R. A. (Pat) Reeder. Superintendent of Motive Power and Rolling Equipment, Reading Company, Reading, Pa. Active for many years, especially at Railroad sessions. Attended nearly all annual meetings.

1923 J. J. Siegfried. Road Foreman of Engines, Gulf Mobile and Ohio Railroad, Bloomington, Illinois. Has attended meetings for years.

1926 H. Kenneth Kugel. Formerly Smoke Commissioner, Cleveland, Ohio, and for many years Chief Engineer, Smoke and Boiler Inspection, District of Columbia. Very active in the Association. Has probably attended almost every meeting since he joined. Served on many committees and was Chairman of the Nominating Committee several times. Served as President of the Association in two different years. He is at the present an Honorary Member of the Association.

ZONING STANDARDS

(*Continued from page 160*)

(1947) (collecting cases).

2. See, e.g., Petropoulos vs. Chicago, 5 Ill. 2d 270, 125 N.E. 2d 522 (1955); Tower Cabana Club, Inc. vs. Chicago, 5 Ill. 2d 11, 123 N.E. 2d 834 (1955); Regner vs. County of McHenry, 9 Ill. 2d 577, 138 N.E. 2d 545 (1956).
3. See, e.g., Tower Cabana Club, Inc. vs. Chicago, supra; Dube vs. Chicago, 7 Ill. 2d 313, 324, 131 N.E. 2d 9 (1955).
4. Dube vs. Chicago, supra.
5. See, e.g., Exchange National Bank vs. County of Cook, 6 Ill. 2d 419, 129 N.E. 2d 1 (1955); LaSalle National Bank vs. Chicago, 5 Ill. 2d 344, 125 N.E. 2d 609 (1955); and the cases cited in reference 2.
6. 197 Ill. 20, 63 N.E. 1086 (1902).
7. See, e.g., Exchange National Bank vs. County of Cook, supra; LaSalle National Bank vs. Chicago, supra; and the cases cited in reference 2.
8. Goldman, in Handbook of Noise Control, Chapter 11, McGraw-Hill (1957).
9. Goldman, supra.
10. Kennedy, "Fifty Years of Air Pollution Law," J. AIR POL. CONTROL ASSOC., 7, No. 2, p. 125 (Aug., 1957).
11. Davis, The Requirement of a Trial Type Hearing, 70 Harv. L. Rev. 193, 262 (1956). See Londoner vs. Denver, 210 U. S. 373 (1908).

DESIGN ATTITUDES

(*Continued from page 113*)

with past unit designs has been disappointing. Although it is acknowledged that limited success has been achieved in improving their performance in such cities as New York, Chicago, and Detroit, it is conceivable that if impetus is not given to the development of new designs, apprehension, poor experience, rumor, etc., will dictate that waste disposal techniques other than flue-fed incinerators will be used for multiple story purposes.

REFERENCES

1. Sterling, Morton, Bower, R., Testing of Domestic Incinerators, Paper No. 58–29, 51st Annual Meeting, APCA, 1958.
2. Refuse Collection and Disposal, *The American City*, April, 1952.
3. Gabbert, W. L., Equipment for the Collection of Fly Ash, Dust, Soot, and Smoke from the Flue-fed Incinerator, *Air Repair*, **4**, Nov., 1954.
4. Reed, R. J., Truitt, S. M., Selecting Incinerator Smoke and Odor Burners, *Air Repair*, **4**, Nov., 1954.
5. Kaiser, E. R., Halitsky, J., Jacobs, M. B., McCabe, L. C., Performance of a Flue-fed Incinerator, Paper No. 58–14, 51st Annual Meeting, APCA, 1958.

COMMITTEE REPORT

(*Continued from page 171*)

- Botanical products
- Inorganic and organic medicinal chemicals
- Pharmaceutical preparations

Paints and allied products
- Paints and varnishes
- Inorganic color pigments

Fertilizers

Gum and wood chemicals
- Hardwood distillation products
- Softwood distillation products
- Naval stores (turpentine and rosin)
- Natural tanning and dyeing materials

Vegetable and animal oils
- Cottonseed oil
- Linseed oil
- Soybean oil
- Grease and tallow
- Fatty acids

Miscellaneous chemical products
- Printing ink
- Toilet preparations
- Glue and gelatin
- Carbon black
- Compressed and liquefied gases
- Insecticides and fungicides
- Herbicides
- Chemical products not elsewhere classified

Committee Members

The TI-2 Chemical Industry Committee is made up of the following men: A. N. Heller, Chairman, E. M. Adams, D. C. Braun, E. Q. Camp, W. W. Hodge, B. C. Newbury, W. Penfield, F. L. Seamans, J. S. Sharrah, O. C. Thompson, R. H. Wilson, W. C. Wooding, Jr., and J. E. Yocom.

INDUSTRIAL ZONING

(*Continued from page 155*)

basis. As the urbanization extends into surrounding areas, the jurisdictional area should adapt to the change.

4. Compliance to the air zoning regulation by local agencies within the jurisdictional area should be mandatory.

5. Close liaison should be established between the air pollution control and the planning agencies regarding population forecast, economic base, land use, zoning, traffic, and other studies of mutual concern.

6. Within the jurisdictional area the size of the zoning districts will be dependent on the refinement possible to distinguish and measure mesometeorological variables affecting atmospheric dilution capacity.

7. For ease of comparative study between urban areas and for historical reference within an area itself, uniform definitions and standard classifications and procedures should be adopted.

REFERENCES

1. Arnold O. Beckman, et al., Report of Special Committee on Air Pollution, Report to Governor Goodwin J. Knight's Air Pollution Control Conference, Los Angeles, p. 14 (Dec. 5, 1953).
2. Southern California Air Pollution Coordinating Council, Minutes of the Meeting, California Hotel, San Bernardino, Calif. (Aug. 18, 1958).
3. Los Angeles Chamber of Commerce, An Area-Wide Plan of Action to Eliminate Air Pollution—A Policy Statement, Los Angeles: Program No. 5, The Chamber (Sept. 29, 1955).
4. Harold W. Kennedy, Legal Aspect, Prohibiting Industries that Cannot Control Air Pollution, County Counsel Opinion to the Los Angeles County Board of Supervisors (July 6, 1956).
5. University of California, The Bureau of Public Administration, Adopting Government to Metropolitan Needs. Prepared for the California Assembly Interim Committee on Conservation, Planning, and Public Works, Assembly Interim Committee Reports, 1955–1957, Vol. 13, No. 11, Sacramento: California State Printing Office (Jan. 1957).
6. G. P. Larson, J. C. Chipman, and E. K. Kauper, A Study of Distribution and Effects of Automobile Exhaust Gases in Los Angeles. Presented at the Annual Meeting of the Society of Automotive Engineers (Jan. 10–14, 1955).
7. M. Neiburger, Tracer Tests of Trajectories Computed from Observed Winds. Report No. 7, Air Pollution Foundation, Los Angeles (Apr. 1, 1955).
8. Dennis O'Harrow, "Performance Standards in Industrial Zoning," *Planning, 1951*, Chicago, American Society of Planning Officials, pp. 42–55 (1952).

• • • Personalia • • •

Leroy Diehl, air pollution control commissioner of Cleveland, Ohio, and a city employee for 19 years has retired from his post. Mr. Diehl, originally named as an inspector in the smoke abatement bureau, was used extensively as a trouble-shooter in emergency assignments before being tapped to take full charge of the pollution control division. He is 69 and has been in poor health for more than a year though he worked regularly until recent weeks.

* * *

Theodore K. Cleveland, Ph.D., has been appointed by the Board of Directors of the Bay Area Air Pollution Control District to serve on the district's 20-man Advisory Council.

Dr. Cleveland is vice president in charge of Research and Development for the Philadelphia Quartz Co. of Calif., Berkeley. He fills the vacancy on the Council which was created when Ivan L. Johnson, who is president of Pacific Steel Casting Co. in Berkeley, was forced on doctor's orders to resign.

The new Council member was born in Canada and moved to Berkeley early in 1935. He received his Ph.D. in organic chemistry from Yale University in 1925.

* * *

Donald F. Adams, head of the Washington State University's Industrial Research Division's air pollution section, has accepted an appointment under which he will serve as chairman of the air pollution instrumentation committee of the Instrument Society of America.

Mr. Adams' committee is part of the Society's Analysis Instrumentation Division headed by H. J. Noebels, Beckman Instrument Co., Fullerton, Calif. It was created this year in order to provide a central clearing house where information dealing with the instrumentation of air pollution would be handled.

In his new role, Mr. Adams will preside over an air pollution instrumentation symposium at the spring meeting of the Instrument Society in San Francisco next May.

* * *

William T. Ingram, Consulting Engineer, has opened a West Coast office with **Fred R. Ingram** as Associate in charge of that office.

The professional services offered by both the East and West Coast offices provide sanitary engineering consultation concerned with control of environment and include water purification, sewage and industrial waste treatment, air pollution control, industrial hygiene, and related research planning and design. The service is made possible through the co-operation of professional specialist consultants in several areas including sanitary chemistry, meteorology, and mechanical engineering, who are associated with activities of either office as the need arises.

Fred Ingram brings to the staff a general background of civil and sanitary engineering and a specialist's experience in industrial hygiene and air pollution control.

* * *

Dr. James P. Lodge, chief of air pollution chemistry at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, has been named one of four editors of the International Journal of Air Pollution, a widely known scientific journal published in London, England. Dr. Lodge will be responsible for all articles contributed from the western hemisphere. The other editors are R. F. Storer of Imperial College, London; G. Nonhebel of Imperial Chemical Industries, London; and Professor John Pemberton of Belfast, Ireland. Dr. Lodge is also chairman of the atmospheric chemistry committee of the American Geophysical Union and a member of the air pollution committee of the American Chemical Society.

(*Continued on next page*)

FOR YOUR INFORMATION

We have available reprints of the TA-6 Committee's Stoker Manual that appeared in the November Journal of APCA. Price depends on number of reprints desired. Write: Executive Secretary, APCA, 4400 Fifth Avenue, Pittsburgh 13, Pa.

* * *

APCA Headquarters has had several inquiries from libraries concerning back numbers of *Air Repair* and the JOURNAL of APCA which they want for binding. We would be very happy to pay 50¢ a copy for any of the following issues:

Volume I	—No. 2	Nov., 1951
	No. 3	Feb., 1952
	No. 4	May, 1952
Volume II	—No. 1	Aug., 1952
Volume IV	—No. 2	Aug., 1954
	No. 3	Nov., 1954
Volume VIII	—No. 1	May, 1958

Please contact APCA Headquarters if you have any of these.

BCI MERGES WITH NCA IN MARKETING DEPARTMENT

On January 1, 1960, BCI became the Bituminous Coal Institute Division of the Marketing Department of National Coal Association. As the market promotion agency of NCA, the BCI Division will continue to direct its activities toward full consideration of coal by plant management, architects, and consulting engineers wherever and whenever a fuel selection is to be made.

W. W. Bayfield, formerly executive vice president of American Coal Sales Association, now merged with NCA, is vice president in charge of the newly created Marketing Department. Carroll F. Hardy, formerly managing director of BCI, is director of the BCI Division. Harry C. Ballman, formerly manager of BCI field engineering services, is director of the Air Pollution Control Division.

Paul L. Brown, formerly in charge of ACSA's salesmen and management training program, is director of the Manpower Development Division. The Marketing Department will also supervise the management of Automatic

(*Continued on next page*)

Section Hi-Lites

(*Continued from page 172*)

mobile exhaust to damage plants and to cause eye irritation.

The present co-operative study is designed to avoid many of the criticisms of the earlier studies. In particular, Dr. Nicksic cited the photochemical facilities, the gasoline blends used, the data on emissions, and the smog potential of the hydrocarbons replacing the olefins in the gasoline as items to be critically examined. Although curves of hydrocarbon concentrations vs. eye irritation reaction times for gasolines of varying olefin contents showed differences at higher concentrations, Dr. Nicksic pointed out that at low concentrations such as are found in the atmosphere, around 1 ppm, the curves overlapped. This could indicate that the variation in fuels might not be as important under actual atmospheric condition as thought. It was the contention of the APCD that the olefins in the C_4 to C_7 range are the important contributors to the eye irritation potential of automobile exhaust and are related to the olefin content of the fuel. Dr. Nicksic agreed that the amount of C_5 and C_6 olefins in the exhaust gases varies with the olefin content of the fuels, but pointed out that these olefins are only a minor portion of the total olefin content of exhaust gases.

Personalia

(*Continued from page 175*)

The Buffalo Forge Co. announced the election of **Milford E. Reiner** to the Board of Directors.

Mr. Reiner joined the Company as assistant Controller in 1941, was promoted to Controller in 1955, and appointed Treasurer in 1959. He was associated with Ernst and Ernst for 16 years, where he supervised the handling of the Buffalo Forge Co. account. Mr. Reiner received his Certified Public Accountant designation after completing the required work at the University of Buffalo.

* * *

Appointment of **D. A. Harrington** to the Kansas City office of The Day Sales Company, Minneapolis, has been announced by Max R. Springer, company president.

Mr. Harrington joins The Day Sales Company with 10 years of sales and engineering experience in air handling equipment and related fields. For the past two years he has been a sales engineer for McNamara Sales Company, St. Paul, Minn. He previously served in the sales department of Manners-Motz Company, St. Paul, and he served also in the capacity as a mechanical engineer for the Crane Company of Minnesota.

* * *

V. Murgaski, President of Research Development and Surveys Associates of Toronto announced the appointment of **Charles Newbury,** B.Sc., as senior associate in charge of the Pollution and Combustion Division. Mr. Newbury was formerly a Fuel Engineer at the headquarters of the British Ministry of Fuel and Power in Whitehall, and he also has acted in the capacity of Assistant Director in charge of the Pollution Laboratories at Ontario Research Foundation.

* * *

William E. Archer has been promoted to the position of Manager of Research and Development for the Western Precipitation Division of Joy Manufacturing Co., Los Angeles, Calif. The announcement was made by A. W. Knight, president and general manager of the division.

Mr. Archer joined Western Precipitation in 1950 as a service engineer in the New York office, later moving to the home office which is located in Los Angeles. He most recently was Chief Development Engineer for the division, which involved among other things directing the gas flow and design studies of electrostatic precipitators and experimental work on new types of Multiclone mechanical dust collectors.

NEW GRAD STUDY SET UP AT CIT

The California Institute of Technology is establishing a new program of graduate study in Environmental Health Engineering. The W. M. Keck Engineering Laboratories, now under construction, will be the site of the graduate training and research. It is scheduled for completion in September, 1960.

Environmental health engineering deals with the impact of man on his environment and the effects of these environmental changes on man. Air pollution, water quality, sewage and industrial wastes, radioactive substances in water and sewage, new chemicals, occupational hazards to hygiene, and many other factors will be explored for new engineerings principles at Caltech.

The program is largely for candidates for the Ph.D. degree, most of whom will spend three years or longer at the Institute.

Requests for catalog and application forms should be addressed to: Dean of Graduate Studies, California Institute of Technology, Pasadena.

* * *

Appointment of **Robert F. Stewart** as Vice President and Assistant General Manager of Western Precipitation Division of Joy Manufacturing Co., Los Angeles, Calif. was announced by A. W. Knight, president and general manager of the division.

Prior to this appointment Stewart has been vice president for sales of the dust collecting equipment of the division. He has served in a number of capacities including sales engineer, chief estimator, and sales manager since joining Western Precipitation in 1946.

In his new position he will direct and control all departments and activities of the Western Precipitation Division under the general policy direction of the general manager.

* * *

Pat Zilliacus was appointed manager of agency sales for the Western Precipitation Division of Joy Manufacturing Co., Los Angeles, according to R. F. Stewart, Vice President for Sales of the division.

Mr. Zilliacus was formerly with the Industrial Division of Joy and prior to that was General Manager of the Strick Trailer Co., a division of Fruehauf Corp. He is a graduate of the University of Maryland with a B.S. in mechanical engineering, and of the University of Pennsylvania with an M.S. in electrical engineering. He is also a member of the National Society of Professional Engineers and the American Society of Mechanical Engineers.

G. H. YOUNG ASSUMES DR. HAMOR'S APCA DUTIES

Since Dr. W. A. Hamor's retirement from Mellon Institute left APCA without an advisor, Dr. George H. Young, Director of Research, has been appointed to that post.

Dr. G. H. Young

Dr. Young joined the research staff of Mellon Institute late in 1935, as the first incumbent of the Stoner-Mudge Co. Multiple Fellowship on Protective Coatings. His education includes a B.S. in chemistry from Pennsylvania State University, with an M.S. and Ph.D. in organic chemistry.

In 1937 he was made Senior Fellow, which position he held until 1944, when he was named Executive Assistant to the Director of Mellon Institute. In 1947 he became Assistant Director, and a Director of Research in 1951.

In his present position Dr. Young has responsible charge of certain government contract negotiations, security, and a few other internal administrative matters. He serves as patent adviser to the Institute's scientific personnel. He continues to supervise research in the fields of fundamental and applied organic chemistry, resin technology, coatings, glass technology, air and water pollution, and other projects.

BCI Merges with NCA

(*Continued from page 175*)

Solid Fuels Equipment, Inc., the name of which has been changed to Bituminous Coal Equipment, Inc. Frank Kirkpatrick will continue as managing director of BCE, Inc., under the direction of Mr. Bayfield.

Within the BCI Division, Glynn L. Coryell, formerly director of engineering, NCA, is manager of field operations in charge of the BCI staff of district engineers; Victor V. Lehtoranto is manager of market research; Charles H. Marks is manager of engineering.

Ord Alexander, formerly of NCA engineering, is engineering manager, government services operations; Thomas J. Fitzmorris, formerly BCI technical editor, is manager of publications; Robert T. Snure, formerly ACSA bulletin editor, is associate manager of publications. Other BCI personnel and assignments remain unchanged.

At Western Precipitation Mr. Zilliacus will be responsible for all product sales made through manufacturers agents and the other divisions of Joy.

Clearing the air of mystery for APC...

Beckman Infrared Analyzers are widely used in air pollution research by many private industries and government agencies. Positive, non-dispersive instruments, accurate to ±1%, provide fast response detection of most gases from ppm to 100% full scale. Making complex analyses with direct reading output, subject to automatic control and standard cycling, they are helping to speed the day when these vital control problems will be removed from public concern. For permanent installations in continuous process control and for stack gas analysis, the rugged industrial Model 21 is the proven answer. For laboratory and pilot plant use, the Model 15-A is best suited. For exhaust gas studies of CO, CO_2 and hydrocarbons, under actual operating conditions, the Model 28 is designed for mounting in an automobile. Also available are instruments for the continuous analysis of total oxidants (ozone), NO, NO_2 and SO_2 which are proving their reliability in a wide variety of applications. Beckman Application Engineering is further assurance of proper instrument and accessory selection to meet your specific performance requirements. For complete details write for Data File 84-4-10.

Beckman
Scientific and Process Instruments Division

INSTRUMENTAL IN YOUR FUTURE 25 YEARS 1935-1960

Beckman Instruments, Inc.
2500 Fullerton Road,
Fullerton, California

is this the PRICE OF PROGRESS?

IT DOESN'T HAVE TO BE —

and we can help prevent unnecessary air pollution by providing assistance in these areas:

MICROMETEOROLOGICAL SURVEYS • SITE SELECTION •
DISPERSION CALCULATIONS • WIND TUNNEL STUDIES • STACK AND BUILDING DESIGN AND ORIENTATION •
STACK EMISSION INVENTORIES • ABATEMENT EQUIPMENT EVALUATION • COMMUNITY SURVEYS •
AIR SAMPLING • TRACER STUDIES

For an explanation of how we can assist with your particular problems address inquiries to us at 3272 Peachtree Road, N. E., Atlanta 5, Georgia.

LOCKHEED Nuclear Products

LNP

ATLANTA MARIETTA DAWSONVILLE
GEORGIA DIVISION LOCKHEED AIRCRAFT CORPORATION